The Journal

OF THE

Royal United Service Institution.

VOL. X. 1866. No. XXXVIII.

Evening Meeting.

Monday, January 15th, 1865.

CAPTAIN E. GARDINER FISHBOURNE, R.N., C.B., in the Chair.

NAMES of MEMBERS who joined the Institution between the 1st and 15th January, 1866.

ANNUAL.

Jackson, J. H., Ensign 90th Regiment. 1*l.*
Beadon, O. A., Lieut. Royal Marine Light Infantry. 1*l.*
Durrant, F., Lieut. R.N. 1*l.*
Clementson, Charles, Lieut.-Col., Northumberland Artillery Militia. 1*l.*
Robinson, C. W., Lieut. Rifle Brigade. 1*l.*
Montgomerie, A. W., Capt. 20th Hussars. 1*l.*

THE NECESSITY FOR BUILDING UN-ARMOURED SHIPS OF WAR.

By Captain W. HORTON, R.N.

ALREADY twice within twelve years have we heard of reconstruction of the British Navy.

Considerations of improved efficiency of individual ships on the pattern, more or less, in either case, set before us by the French, have led to these expensive changes which have been followed in their own degrees by other European nations.

The remaining navies of Europe, that of France excepted, have been hitherto inconsiderable; but the same means of improvement adopted elsewhere, and consequently thrust upon this country, have rendered almost equally powerful with the fleet of France, those of both Italy and Russia. Iron-clad ships have also found favour in Austria, and even in Turkey, while the restoration of the Spanish Navy to a prominent position is a very popular idea in that country, and not unlikely to be fulfilled under the rapidly increasing wealth and prosperity of a kingdom which numbers upwards of 60,000 enrolled seamen along her Atlantic and Mediterranean coasts.

I mentioned considerations of efficiency of ships as having led us on to reconstruction, first in establishing a magnificent force of ships of the line, and powerful frigates and corvettes propelled by steam, then in calling into existence a number of iron-clads, which has ever and anon been counted over and compared with those of France, people being content in general to measure our strength according to that of our ancient adversary—our recent rival and ally—and to omit from the question altogether political combinations which, were they to arise in less quiet times than these, might bring into array against us a vastly superior force of those expensive and now much-criticised iron-clad ships. With properly armed and efficiently turretted armour-ships, supplemented by the powerful forts and batteries now in course of construction or completion, and yet further aided by a properly organised system of torpedo defence, we may trust, under Providence, to defy as heretofore, the attack of our own shores by the world in arms.

In the years, however, which have elapsed since the invasion of this country was happily averted by our great naval triumphs of the last generation, so great a change has come over the nature of our colonial possessions, colonial population, and maritime commerce, that political considerations of a different character cannot fail, ere long, to dictate the nature of such changes as we must see, take the place of the two recent re-constructions.

Re-formation, or re-organisation would be more fitting terms to apply to that which must soon and surely ensue, including a speciality of certain classes of ships adapted for certain services.

We witnessed during the late lamentable strife between the Federal and Confederate States of North America, what serious injury could in a short time be inflicted upon the extended commerce of their powerful adversary, by a comparatively weak confederation, possessing no navy whatever, through the skilful employment of some small and indifferent vessels, surreptitiously obtained from this country.

The Northern commerce was completely paralysed by the seeming ubiquity of the "Sumter," the "Alabama," and a few more casual cruizers, all of a very inferior description. The fixed determination of purpose which enabled the North to prevail at length, after four years' strife, and to maintain the Union whose disruption was at stake, caused the adoption of wise measures for carrying that purpose into effect, and all sacrifices at sea were unresistingly borne with, in order that the blockade of the Southern coasts might be maintained as efficiently as possible.

The lesson learnt at such prodigious cost was not thrown away upon the hard-headed, astute statesmen who hold high office in the United States, and who carry vigorously into effect whatever measures they deem to be for their country's welfare.

Accordingly, before the war was at an end, it was determined to establish a class of vessels for foreign service possessing great speed, and carrying very heavy guns, which, if they at all approach the idea upon which they were designed, will have it in their power, so long as they continue unopposed by more numerous ships of superior, or at least of equal speed and armament, effectually to sweep the seas of any commerce against which they may be launched. Such ships will

be fit to fight on favourable terms when the occasion may arise, and able to flee beyond possibility of capture, from any description of vessels now existing elsewhere, and which might happen to carry a superior armament or thicker sides. Having for their object the annihilation of our enemy's commerce on the sea, they would scarcely stop in their "Alabama"-like career of depredation to measure their strength against an adversary better armed than themselves.

Viewing this statement from the opposite side, it would appear that in competition with such ships, any that we now possess would be eqally unfit to fight them when such might be their policy, and incapable of overtaking them if they chose to run away. The conditions of a contest between opponents thus unequally matched are such as cannot be contemplated with much satisfaction from our view of the case, as it now stands.

In pursuing this policy, the Americans are following out the principle which has ever governed their naval administration. Since they were a nation, it has been their object to possess some one class of vessels enjoying a manifest superiority over the corresponding class in our Navy.

We suffered in bygone times from their use of long guns, as opposed to carronades, and from their employment of heavy frigates, with which we had none fit to compete on equal terms.

The gallant action of the "Endymion" with the "President," and the noble heroism which made the "Chesapeake" fall prize to the little "Shannon" in 15 minutes, were as cheering lights in a dismal view: but they scarcely sufficed to dispel the gloom which hung over most of our naval actions in the last American war, from 1812 to 1815. Our crews fought bravely, and were bravely led against those who were their equals in every other respect, whilst fired with the double impulse of excited hate and fear of the halter, fighting in superior numbers, wielding better weapons, and flushed with the success attending their contest with an enemy whose force was inferior to them in every instance in which they were engaged.

Opposing to those of the enemy, smaller ships, feebly armed and thinly manned, was the means by which the Government of that day contrived to tarnish the glory of the British flag in the eyes of a world little informed as to the real merit of the actions which took place.

Let us trust that no future time, should war unhappily arise, may witness the navy of Great Britain contending on such miserably unequal terms against the enemies of their country, armed with every advantage which science, bravery, and nautical skill could embark on their side. Yet, we seem to trust, as a nation, to that favouring Providence alone, which has hitherto helped us out of every difficulty,—forgetting, to all appearance and on all occasions, the ancient adage that "the gods help those who help themselves."

The early onslaught of a sudden war will surely test our state of preparation, leaving little time, perchance, for that bringing up of *leeway* for which the tardy operations of former times gave place, and by which we were enabled through superior sources at hand, as compared with those then at the command of our enemies, to leave off on

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better terms than those on which we had begun. It is obvious that in the present day, howsoever great may be our own resources, the comparison with those of other nations is less remarkable than formerly, and I shall presently show that the impulse of a civil war called forth the energies of manufacturing skill in the United States in a manner not to be overlooked, if, indeed, to be equalled in this country. And as in the daily operations of life, the willing giant steam is made to spare the sinews of thousands of men and tens of thousands of horses in producing the materials in question, so should the very best and fittest weapons be prepared beforehand, and placed in the hands of a nation's warriors in the day of trial, if they are expected to win her cause by their skilful use of them. For, as little could the labour be accomplished without the aid of steam, by which those ships are built and those weapons manufactured, as men can have it in their power to overtake fast ships with slow ones, or to keep on an equality in fighting, when small guns and few of them, are opposed to heavy guns in larger numbers.

None but the very fastest ships, armed with the very best guns that can be put into them at the time, should be opposed to those, be they weak or be they strong, with whom we may have to contend.

Unity of design and fixity of purpose appear ever wanting under our Parliamentary Government, where the intentions of one Administration are rarely those of their successors, and where spasmodic efforts, ofttimes the consequence of popular panic, are as often misdirected. With great energy we produced in no long time a considerable fleet of screw ships of the line. They still exist in our ports, but they have lived their little day of usefulness, and are acknowledgedly unfit to cope with any iron-sided ship, however inferior to them in armament and crew.

These have, therefore, taken the place of the others as the exponents of our naval force; but they would, as a combined fleet, operate under one very great disadvantage against a French force of equally powerful armament.

Omitting, for the sake of argument, the question of whose plates are thickest, or whose guns the best, the French ships are designed so much under one idea, and with qualities for carrying that idea into effect, that they are able to manœuvre under steam with very great precision.

Our own may possibly be classed, in point of speed, in three squadrons, comprising respectively the first six ships in the subjoined list as a 14-knot squadron, the second six as going 13 knots, and the next five going 12 knots; but even these varieties of ships differ among themselves, perhaps (excepting the "Defence" and "Resistance"), in respect of sea-going qualities and turning power; while what remain of our 32 iron-clad ships, large and small, complete, or in course of completion, are a miscellaneous collection, no two of which, however excellent as individual ships, would recognise each other as sisters.*

* From this statement I must except the "Birkenhead Rams," ("Scorpion," and "Wyvern"), which, as regards hull and engines, are precisely similar.—W.H.

Speed on trial at measured mile.	Names.	Horse-power.	Guns.	Tonnage.
Knots.				
	Minotaur	1350	26	6621
15·487	Agincourt	1350	26	6621
	Northumberland	1350	26	6621
14·358	Achilles	1250	20	6121
14·356	Warrior	1250	32	6109
14·215	Black Prince	1250	41	6109
12·94	Caledonia	1000	35	4125
13·533	Lord Clyde	1000	24	4067
13 ?	Lord Warden	1000	24	4067
13·119	Prince Consort	1000	35	4045
12·896	Ocean	1000	23	4047
14 ?	Bellerophon	1000	14	4246
12·36	Hector	800	24	4089
11·433	Valiant	800	24	4063
13 ?	Royal Alfred	800	18	4045
	Zealous	800	20	3716
12·529	Royal Oak	800	35	4056
11·618	Defence	600	16	3720
12·332	Resistance	600	16	3710
12·5 ?	Penelope (twin screw)	600	10	2947
13 ?	Pallas	600	6	2372
11·819	Favourite	400	10	2094
10·354	Research	200	4	1253
9·944	Enterprise	160	4	993
11·86	Viper	167	2	737
9 ?	Vixen	160	2	754
9 ?	Waterwitch	167	2	778
	Turret Ships.			
12·253	Royal Sovereign	800	5	3765
10·5 ?	Prince Albert	500	4	2529
10·515	Scorpion	350	4	1857
10·059	Wyvern	350	4	1857
12·171	Amazon		4	1081
	Floating Batteries.			
	Erebus	200	16	1954
	Terror	200	16	1971
	Thunderbolt	200	16	1973
	Ætna	150	16	1588
	Thunder	150	14	1469

These ships have not all been tried.—W.H.

In this list of 32 ships (not counting the 5 floating batteries), there are 11 classes in respect of guns, 10 in point of horse-power, and 9 classes of tonnage. The grand total of guns is 616; of horse-power, 24,354; and of tons, 120,379; ships, 37.—W.H.

I wish particularly to impress upon the meeting that I have not prepared this statement with the object of finding fault. Our ships may be, and probably are, very superior, taken collectively or otherwise, to the iron-clad force of any other nation.

I have drawn up this table for the sake of pointing out how one Government may adopt a principle, and work it out with determination of purpose, while that of another nation may accumulate most valuable

FRENCH IRON-CLADS.

From "Statesman's Year Book, 1866."

	Guns.	Horse-power.
Magenta	52	1000
Solferino	52	1000
Couronne	40	900
Normandie	36	900
Invincible	36	900
Gloire	36	900
Provence	36	900
Héroïne	36	900
Savoie	36	900
Revanche	36	900
Surveillante	36	900
Flandre	36	900
Guyenne	36	900
Gauloise	36	900
Valeureuse	36	900
Magnanime	36	900
Taureau (cupola, ram)	1	500
Tormante	16	225
Dévastation	16	225
Lave	16	225
Foudroyante	16	225
Congrève	16	225
Saigon	14	300
Palestro	14	300
Peiho	14	300
Paixhans	14	300
Protectrice	4	150
Impregnable	4	150
Embuscade	4	150
Refuge	4	150
Arrogante	4	150
Implacable	4	150
Opiniâtre	4	150
Ships 32	777	18,575

Divisible into 5 classes + 1 ram.—W.H.

Three more frigates and 7 corvettes were begun in 1865.

When the French ships left Spithead for Cherbourg, the signal was made to proceed at 12 knots; and they arrived at their destination accordingly, with the utmost punctuality. How many iron-clads out of our 32 could have obeyed a similar order? We know, from the similarity of the French ships, that 16 at least of theirs could have done so. Any improvement of their armament will in like manner affect all their ships of each class in a similar degree.—W.H.

individualities without arriving at an aggregate of corresponding value. *Perhaps the classification of our ships in groups may commend to more favourable consideration the French method of manœuvring in small squadrons, or *pelotons*, composed of ships possessing equal speed, and similarity of turning power.

Let all these ships be assembled as a fleet, or even suppose their distribution to be regulated with such judgment as that corresponding squadrons at least should be complete and kept together, and let two or three such squadrons assemble for performance of some particular service.

Their variety of speed and of turning power is so great, and so little brought into practice with relation to each other, that they would certainly appear as if brought together for the sake of contrast. Steam tactics, on an extended scale, may be estimated at so many hundred pounds sterling per diem, and without practice in steam tactics, such squadrons would be in constant danger of collision, or at least of the worst confusion, whenever darkness or thick weather supervened; and the inconvenience of possessing so many dissimilar classes of ships would be seriously felt by all concerned.

The ships in question may be individually very superior to the French, as I believe they are—better armed, more thickly clad, and provided with much more ingeniously expensive contrivances for a variety of uses, necessary or otherwise.

Tactics may, as regards engaging an enemy, be very possibly obsolete. Indeed, I doubt whether the best way of handling such a force of ships as these, would not be to render the attack as confused as possible, in order to confound the intended measures of the enemy, and so leave each ship to do the best she could by tackling one of them in the closest fight achievable; but such is not, perhaps, their rightful use.

To succeed in even this, however, it is needful to have the ships in presence of each other beforehand, in order to avoid delay or disadvantage when an engagement is in prospect. Secondly, for this end certain tactics are undoubtedly required; and for the due execution of technical manœuvres a greater similarity of ships is highly essential, if not absolutely necessary, especially in narrow seas and winter weather.

I am not sufficiently informed to be able to state how many ships of the French squadrons manœuvre in company, or with what degree of success; but the similarity of many of their ships, and their known power of keeping together at sea, offer sufficient contrast with the variety which prevails among our own, to illustrate how important are unity of design and consistency of purpose in the reconstruction of a navy.

Discussions in the House of Commons and observations in the public press of this country, as well as the development of gun-power, have

* An elementary trial of this system was made under Admiral the late Lord Lyons, in 1858, upon a plan drawn up by me. It was not unattended with success during a trial of many days and nights, performing every variety of manœuvre, even though the eight ships varied in size from the "Royal Albert," 131, to the "Vigilant," 4.—W.H.

no doubt exercised much influence on the fitful production of our iron-clad navy, causing frequent change of purpose, and modification of design. In France, meanwhile, the imperial programme of 1859 has been steadily wrought out in furtherance of that laid down by a decree of Louis Philippe, and modified only by the introduction of iron-clad ships as a substitute for screw ships of the line, since their successful inauguration before Kinburn in 1855.

The Napoleonic idea has been to establish an invulnerable escort for a fleet of transports capable of conveying a fully equipped force of all arms numbering 45,000 or 50,000 men. Its organisation with that object, if not perfect, has at least been for some time complete. The transports now are the dismantled line-of-battle screw-ships of a few years since. Other transports of beautiful form, and apparently capable of attaining high speed, are fitted for conveyance of horses and artillery.

Nothing, in short, is wanting but the Napoleonic will, to test the efficiency of such an equipment on the first convenient opportunity; but happily there is no longer any prospect of the experiment being made against a country whose citizens of all classes have become her defensive force, and with which country the relations of commerce have so immensely increased of late.

All other nations besides France are availing themselves largely of the turret system of central armament, the merits of which have been sufficiently set forth through the ability and steadfast perseverance of Captain Cowper Coles, to have at length overcome all the objections which prejudice could suggest, or which other considerations could dictate.

Let us trust that the day must be already near at hand when tardy justice shall be done to the value of his invention, and when sea-going turret-ships shall enable us to maintain an iron-clad force in distant seas, having coppered bottoms, steel frames, a shotproof belt and turrets, iron upperworks, and perhaps tripod masts.

Placing these in the first category as of imperative necessity to secure supremacy on the ocean, let us consider in the second place his turret-ships for Channel service. These may clearly be almost without masts. Not needing much storage of water or provisions, their space below devoted rather to coals and ammunition, ships for home service may be entrusted to the safe conduct of their engines, while those for foreign stations must have use of masts and sails, with means to feather or to lift their screws.

We may confidently trust the double screws will work themselves into favour sufficiently to overcome the financial scruples of the great engineers, whose pattern ships represent vast capital locked up in models and patterns for every variety of single screw engines adapted to our ships of war. Once overcome this obstacle, which time alone can accomplish, and which must ever delay a change of system, and even our "Warriors" and "Minotaurs" may be rendered trustworthy for narrow seas and channel service.

Counting then upon these two classes of iron-clad ships as able to carry the heaviest description of guns, viz., the sea-going iron-clads (of the future) and the turret-ships for home defence, let us turn our

thoughts to consider the best classes of un-armoured vessels, able either to cut up the commerce of our enemies, or to go forth and cope with such antagonists as now already exist, and will most certainly be employed in event of war with the United States, to intercept and destroy our distant trade.

I will endeavour to place the meeting, as concisely as I can, in possession of a very interesting statement of the steps by which the naval administration of that country was led up to the construction of what represents at present their definite idea.

The document from which I am about to read extracts, is a somewhat lengthy letter from Mr. Donald McKay, the great ship-builder, of Boston, addressed to a local newspaper, the *Boston Advertiser*, and printed in its number of 29th October, 1864.

Referring to former writings of his own, in which he had related what had come under his observation in recent visits to the naval dockyards of England and France, Mr. McKay writes: "I saw that "those powers respected nothing but force, and knew that if we "desired to prevent foreign intervention in our affairs, our navy must "be largely increased."

I apprehend that these views, formed prior to the outbreak of the civil war in America, may, *mutatis mutandis*, be now equally entertained in other countries with reference to the United States.

Let us see then what are the powers of naval development displayed in that great country:—

"At the breaking out of the rebellion (the words are those of "Mr. D. McKay) the navy consisted of the following steamers. The "screw-frigates 'Merrimack,' 'Wabash,' 'Minnesota,' and 'Colorado,' "of about 3,350 tons each; of the large screw-sloop 'Niagara,' of "4,582 tons; of the first-class screw-sloops 'Richmond,' 'Brooklyn,' "'San Jacinto,' 'Hartford,' 'Pensacola,' and 'Lancaster,' of about "2,000 tons each; of the second-class sloops 'Pawnee,' 'Iroquois,' "'Wyoming,' 'Mohican,' and 'Dacotah,' of about 1,070 tons each; of "the third-class sloops 'Narragansett' and 'Seminole,' of about 850 "tons each; of the first-class paddle-wheel sloops 'Susquehanna' and "'Powhattan,' of about 2,430 tons; the 'Mississippi,' of 1,692, and "'Saranac,' of 1,446 tons; and of the small paddle-wheel steamers "'Michigan,' 'Saginaw,' and 'Spitfire,' of about 470 tons each; "making a total of 26 steamers and 49,700 tons."

It may be well to state that the laws of American tonnage represent a larger burthen than is estimated by the present rule in this country; in other words, 100 tons British are equal to more than 100 tons American.

Mr. McKay next tells the speed of these ships, which I beg leave to read, at the risk of being tedious, and without vouching for the ratio between British and American nautical miles. It may possibly approach that which exists here between ships at sea and those on trial at the *measured* mile; nevertheless, the performance quoted does not bear the stamp of improbability. It is as follows:—

"'Niagara,' 10·9; 'Merrimack,' 'Wabash,' 'Minnesota,' 'Roanoke,' "and 'Colorado,' 9; 'Brooklyn,' 9·2; 'San Jacinto,' 8·8; 'Hartford'

" and 'Lancaster,' 9·5; 'Richmond,' 7·5; 'Pawnee,' 8; 'Iroquois,'
" 'Wyoming,' 'Mohican,' and 'Dacotah,' 11·7; 'Narragansett' and
" 'Seminole,' 8; 'Susquehanna' and 'Saginan,' 9; 'Waterwitch,' 9;
" 'Michigan,' 10·5. The 'Pensacola' proved a total failure, and the
" machinery had to be removed."

This statement of speed is very modest, and justifies a reliance on the others made by Mr. McKay. The last fact mentioned also shows that our transatlantic friends no more enjoy immunity from error than do we ourselves.

Let us now learn from him what means were at their command, and what results those means achieved. He says:—

" The means at the command of the Administration for building a
" steam navy were about 2 dozen machine shops, great and small, dis-
" tributed from Maine to Maryland, many of them very small, and
" without the tools, workmen, or skill requisite for the production of
" marine machinery. The first-class shops did not exceed eight in
" number. But the entire force of these shops could not be commanded
" by the Navy Department for construction of new machinery. There
" were the enormous quantity of repairs to the merchant steamers of the
" country to be done, and new construction to be made for that ser-
" vice. The War Department also drew largely on their resources for
" transport steamers, while the locomotive and tool-making shops found
" it utterly impossible to meet the demand upon them. Neither were
" there sufficient raw materials in the country for the large and sudden
" demand. Hundreds of steamers, hundreds of locomotives, shops-
" full of tools, tens of thousands of tons of metal were called for
" instantly, and there was nothing on hand to meet the call. War
" steamers cannot be built in a day. Inexperienced labour cannot be
" converted into skilled mechanics in a day, the prices of machinery
" rose immensely, the pay of the mechanics and the cost of material
" reached a point far above what they were worth, except from the
" factitious cause of the suddenness of the demand.

" The result was felt in the poor materials and poorer workmanship
" with which the machinery was made. Any kind of material and the
" most unskilled labour had to be brought into use, and all this time
" the amount of even that labour was constantly diminishing by the
" absorption of men into the military service."

Here we may learn a lesson of the penalty incurred by a state of unpreparedness. By continuing the story we shall see what can be done with comparatively small resources when strong will gives proper impulse and direction to the use of resources howsoever small.

"In this pressing emergency the Department did all that could possibly
" be done. It purchased every merchant steamer that could be con-
" verted into a blockading vessel or a war cruizer, and the navy at this
" moment contains every merchant steamer of any size or excellence
" that has been built in this country. It set at work every steam-
" engine factory in the land that could produce marine machinery. It
" considered all plans offered for armouring vessels, and tried many. It
" instituted experiments in machinery, in ordnance, and in armour-
" plating. It covered the Mississippi and its tributary waters with an

"immense inland fleet, many of which were armoured, and which "sweeping the rebels from those waters, have been an indispensable "element to our holding the whole interior of the country, as it gives "us the exclusive command of its water highways. It lined the "Atlantic coast with such a blockading fleet as the world never wit- "nessed before, and has practically closed the rebellious district to the "world, the few vessels which succeed in running the blockade being "too small to carry cargo sufficient to give any aid of consequence.

"The rebels have not been able to import even drugs enough to "supply the Medical Department of its army."

Now, these words are not mere "tall talk," they convey a record of facts important to ourselves, and against which we ought not to oppose a foolish self-sufficiency and ill-grounded self-confidence.

The results achieved in the way of ship-building are thus recorded by Mr. McKay:—"The first vessels constructed by the Department "were 23 screw gun-boats of 504 tons each, with a speed of 10 knots "and a draft of 9 feet. They were intended especially for blockading "the mouths of the smaller rivers. The 'Iroquois,' 'Wyoming,' and "'Mohican' were next duplicated, the former twice, in the 'Oneida,' "'Kearsage,' 'Wachusett,' and 'Tuscarora.' The reason for exactly "duplicating them was the fact that as the drawings and patterns were "still in the hands of the original builders, the machinery could be "obtained much quicker, and time was the element of most importance." How wise this course pursued by the Americans, and how different from a system, or want of system, which continues perpetually adding every variety of ships to a navy in which scarcely two agree in any one particular.

"These vessels were followed by the paddle-wheel gunboats "'Maratanza,' 'Mahaska,' 'Sebago,' 'Octarora,' 'Sonoma,' 'Cone- "maugh,' 'Tioga,' 'Genesee,' 'Miami.' 'Paul Jones,' 'Port Royal,' and "'Cimarron,' twelve in number, of about 850 tons each, and having "a maximum speed of 11 knots per hour. To these succeeded 27 "others of the same type, but larger and faster, being of 974 tons "burthen, and having a maximum speed of 14·5 knots per hour.

"Their names are the 'Eutaw,' 'Sassacuss,' 'Wateree,' 'Patuxet,' "'Tallapoosa,' 'Winooska,' 'Mackinau,' 'Shamrock,' 'Tallahoma,' "'Tacony,' 'Tosco,' 'Agawam,' 'Pontoosac,' 'Massasoit,' 'Osceola,' "'Mattabesett,' 'Chickopee,' 'Ascutney,' 'Otsego,' 'Metacomet,' "'Chenango,' 'Lenapee,' 'Mendota,' 'Mingoe,' 'Wyalusing,' 'Pon- "tiac,' and 'Peoria.'"

"Other seven of this class, but still larger and built of iron, have "been lately added, viz., the 'Winnessee,' 'Ashuelot,' 'Muscoota,' "'Suwannee,' 'Shamokin,' 'Mohongo,' and 'Monocacy,' all of 1,030 "tons. These paddle-wheel gun-boats have the light draft of 8 feet, "and carry enormous batteries. They were built for special service in "the narrow and tortuous channels of the shallow sounds and estuaries "of the southern coasts. For these localities where turning was im- "possible, it was necessary they should be double-bowed, *i.e.*, con- "structed with both ends alike, and that their machinery should be "equally well adapted for going forward or back.

"In the autumn of 1861 the Department commenced the construction " of ten second-class screw sloops of war, of about 1,350 tons. They " are the 'Ticonderoga,' 'Lackawanna,' 'Shenandoah,' 'Monongahela,' " 'Ossipee,' 'Juniata,' 'Sacramento,' 'Adirondack,' 'Housatonie,' and " 'Canandaïgua.' They have a maximum speed of 12·25 knots, carry a " large armament, and are efficient ocean cruisers.

" There is now in progress of construction the 'Chattanooga,' of " 3,000 tons, building for the Department by outside parties; also the " 'Idaho,' of similar tonnage, and by other outside parties; while the " Department is itself constructing the 'Madawaska,' 'Wampanoag,' " 'Neshaming,' 'Ammonoosuc,' and 'Pompanoosuc.'

" These vessels are of wood, about 3,000 tons, and intended to have " a speed of 16 knots an hour. They will carry immense batteries, be " full rigged, and will doubtless prove the fastest and most formidable " ocean cruizers ever built by any power.

" There are also in course of building by the Department twenty " first-class wooden screw-steamers, of 2,200 tons each, to have a " speed of 13 knots, carry enormous batteries, and be full-rigged for " ocean cruisers. They will soon be completed." (This was more than a year ago, remember.) "They are named the 'Antietam,' " 'Arapaho,' 'Guerrière,' 'Hassalo,' 'Illinois,' 'Java,' 'Keosanqua,' " 'Keywadin,' 'Manitou,' 'Minnetonka,' 'Mosholu,' 'Ontario,' 'Pis- " cataqua,' 'Pushmataha,' 'Tahgayuta,' 'Wanaloset,' 'Watanga,' " 'Willamette,' 'Contoocook,' and 'Mondanim.'

" While these vessels are building, there have been completed the " 'Nipsic,' 'Shawmut,' 'Nyack,' 'Pequot,' 'Maumee,' 'Kansas,' " 'Yantic,' and 'Saco,' all screw vessels of 593 tons each. The " machinery is from designs of various parties, building to compete " with the Department. The first three having the Department's ma- " chinery, have been thoroughly tried, and can maintain a speed of " 11·5 knots.

" There are now nearly completed the wooden iron-clad coast " steamers 'Tonawanda,' 'Miantonomoh,' 'Agamenticus,' and 'Mon- " adnock,' of 1,564 tons, drawing 12 feet of water, and having two " turrets each, carrying two 15-inch guns. The 'Monadnock' has " been tried, and is found capable of achieving a maximum speed of " 11 knots.

" There are also in process of construction four other iron-clads of " the same type, but larger, and to be faster. They are the 'Kala- " mazoo,' 'Passaconaway,' 'Quinsigamond,' and 'Shackamaxon,' each " of 3,200 tons.

" The Department has also constructed 74 wooden and iron-clad ves- " sels of the 'Monitor' type, with an aggregate tonnage of 78,000 tons.

" There are now in the navy, in active service, 558 steamers, with " an aggregate tonnage of 408,000 tons, against the original 26 steamers " and 49,700 tons with which the war commenced.

" Of this number, 200 steamers, with an aggregate of 241,000, have " been built by the Department. In no country, and with such limited " means and under such difficult circumstances, has there ever been put " afloat, in the same time, such an immense naval armament. . . .

"The naval administration has done all which any naval administra-
"tion could do in such a war.
. . . . . "I have put forth nothing but
"facts, which can easily be verified by reference to official documents,
"and which I deem justly due to our present Navy Department. . . .
"Certainly it cannot be said that in the time of trial the Navy Depart-
"ment has been found wanting."

Most fortunate the Administration which can earn for itself such unqualified praise—and fortunate above most other nations that which can with justice accord it. The Presidential Message of last month states the number of guns in the American navy to have amounted to 3,000, while their crews numbered 50,000 men.

A few remarks upon the foregoing extracts may not be out of place. First, with regard to the much-vaunted "Monitors;" they are entirely out of favour. I cannot say whether the mode of constructing the turrets, wholly different from those of Captain Coles, occasioned disappointments, or whether they are considered to be superseded by torpedoes as a means of defending the coast. Certain of them have been converted into vessels for torpedo service, and the remainder are laid aside as not required for any present purpose. The "Monadnock," as an exception, has been sent round to California.

The verdict against them from some of the admirals was to the effect that the men who had fought in them could never after be kept from under cover when engaged, and this applied to all the iron-clads. That of the officers employed in them was that they were *hell*.

Secondly, Mr. McKay speaks vaguely of "enormous batteries," which may mean anything; but the 15-inch guns afterwards specified are a familiar fact, while we hear of 20-inch guns in course of construction.

I am not about to discuss questions of initial velocity or penetration, but will merely observe that a 15-knot steamer, armed with 15-inch guns, and able with superior speed to range alongside at any period of the 24 hours, would be a very formidable antagonist to the most heavily armoured vessel, mounting the most perfectly rifled guns of the comparatively small calibre employed by us, and possessing the best speed yet realized by any but two or three of our ships of war.

From subsequent information, I learn that the dimensions of some of these ships are as follows:—

"Ammonoosuc" Class.

3,713 tons, 17 to 19 guns.
335 feet long, by 48′ 2″ beam.
To steam 15 knots and upwards.

"Guerrière" Class.

3,177 tons, 21 guns.
313 feet long by 46 broad.
To steam 15 knots.

"Idaho" Class (twin screw).

2,638 tons, 8 guns.
305 feet long by 44 broad.

To steam 15 knots.

There are various other classes, some of which fall short of the original intentions of their constructors, but which may nevertheless prove most valuable cruizers. Their general proportion of length to breadth appears to be about 7 to 1.

I would leave out of the question the use of the stem on the side of the faster ship, and assume that her superior speed will always enable her to avoid that of her iron-clad opponent.

The same superiority will enable her to keep beyond the range of rifled guns by day, without losing the power of closing again at night-fall, when the long range and precision of the rifled guns would become of too uncertain effect to be reckoned as an advantage. Approaching end on, and offering comparatively but a small mark, she would find opportunity to range alongside and deliver such a discharge as would probably sink the antagonist, whether armour-plated or not; for, with guns depressed and fired only when almost touching, the 15-inch shot would probably go out through the bottom, leaving but little chance of safety. Such, it appears to me, would be the tactics to be pursued by a single ship possessing a marked superiority in speed and in calibre of guns. The use of iron under-decks and of an iron inner skin will probably keep within control the incendiary effects of shells exploding between the decks; and where destruction of the ship is the object in view, round shot of large dimensions seem to afford to a very fast ship the best means of achieving that result. The reduced number of guns, leaving available a larger proportion of the crew than formerly for the other duties of the ship, especially for extinction of fire, would point to outward injury by shot as of more serious importance in an action hereafter than the destruction of life or confusion of the crew likely to be occasioned by the explosion of shells.

This argument applies more especially against iron-clad ships whose armour would derive more injury as to sea-going qualities from violent and repeated concussion than from perforation. The iron-clad ship, with plates buckled and bolts distorted, would be left in worse case than her un-armoured wooden opponent with shot-holes plugged and fire extinguished.

Let me not be supposed to argue against a supply of rifled guns to every ship for special uses. Yet, I hold strongly to the belief that very great advantage will attach to the use of spherical shot in future naval engagements as in former ones, whether employed against ships with armour or those without. And while the Americans are increasing yet more the calibre of their smooth-bore guns, it is hardly to be supposed they will allow their largest ocean cruizers to be unprovided with whatever class of guns may be their best from time to time.

It is, moreover, contemplated, if not already arranged, that all ships

in the American navy should be provided with apparatus for the use of torpedoes.

Whether they may ever succeed at sea in landing them on the decks or placing them under the bows of vessels possessing inferior speed, is a problem as yet a long way short of solution; supposing for argument that it could be done, the explosion by means of electricity would ensue immediately, beyond hope of cutting the wire or of ejecting the intruder. The powder for this purpose would be in waterproof bags, to be swung out by whips from the yard-arms.

Whether this mode of putting salt on the bird's tail prove practicable or otherwise at sea, no doubt can exist that an unscrupulous neighbour in a neutral port, provided with these insidious means of destruction, would be a very dangerous companion; and some precautionary device to meet this danger appears to have become very necessary, for we have seen how public applause has greeted the return of officers whose personal ambition or false zeal had led them to commit the grossest outrage on neutrality.

It needs little consideration to accept the fact that vessels such as have been described and of which the full details are in this country, must, while unmatched in speed and sea-going qualities, practically command not only the seas full of our floating wealth, but must also threaten the possession or the security of our colonies in their present undefended state.

Our North American dependencies are too conveniently placed as an ever-ready means of annoyance, for the United States do really aim at their acquisition. For that reason they may possibly remain a practical pledge of peace between the two countries, so long as they continue under the British Crown. They will assuredly at the same time continue to be a perpetual source of threatened annoyance, and of consequent irritation, until declared independent.

With regard, however, to the other colonies of Great Britain, in general,—to assume that foreign nations are deceived by the nominal garrisons and tumble-down batteries in many of our distant possessions over sea, is to behave like the silly bird which buries its head in the sand or mud to seek imaginary security from its foes, or like a child which shuts its eyes and fancies itself unseen by others.

All nations must be aware that in the extended dominions of this country there are hundreds of points at which contributions to any extent could be levied with the same facility and success which attended the buccaneers of old on the Spanish Main.

Nor is it to be supposed that cruizers such as I have just described, would limit their depredations to such ships as they might meet at sea. The colonies and foreign possessions of Great Britain would furnish them with supplies of all descriptions, with abundant plunder, and with a fictitious kind of glory, cheaply acquired, to our great shame and at our expense. For the United States to send forth such cruizers, counting upon such supplies, would be a much more popular and efficacious mode of warfare than to break their heads against the stone forts and iron shields which are being made to line our shores;

still more so than to test their strength against a defensive fleet of iron-clad ships backed by a system of torpedoes.

I will now beg leave to read what many here present may have already seen in the public journals—an extract from a letter of the Prince de Joinville—no mean authority on naval affairs. The letter is dated 28th April, 1865, and appeared in the English papers in October.

Addressing an American, the Prince says:—

"You must be proud, Sir, of the doings of your navy. With the "brilliant exploit of Commodore Winslow, has the tide of victory "turned with you. The achievements of Mobile Bay are without "parallel, and reflect the greatest honour on your flag. All naval "men pay a just tribute of admiration to Admiral Farragut, and his "brother officers and men. This war will leave your navy in a "very efficient state, and with a feeling of confidence in itself which "is one-half of success.

"Not so in European navies.

"Ours is tired and disgusted by the odious service of transports im- "posed upon it. The British navy after a long period of inaction, and "furnished with ships and men it has no confidence in, is not what it "was formerly. Both navies continue to build sea-going broadside "iron-clads of immense size and cost, but the policy of building such "expensive ships when they may be so easily sunk by a miserable "torpedo is much discussed, and the tide is coming to small iron- "clads with two or four guns 'Monitor' fashion.

"For long cruises, fast iron-clad sloops, 'Alabama,' or rather "'Florida' fashion, seem also to be most appropriate. Upon all these "points you have the lead.

"Where everybody is still behind, is in gunnery. The best English "gun is the 300-pounder smooth-bore, muzzle-loader, Armstrong gun, "built on the coil principle and able to throw its shot with a very "heavy charge of powder. The Royal Navy has no good gun of "heavy calibre, but I think Mr. Blakely can turn out some very "efficient ones. The French have no heavy guns, smooth-bore or "rifles, and have not yet succeeded to experiment successfully on any "one. The best gun we have in use is a breech-loading rifle gun, "throwing a 60-lb. shot with a low charge. That gun works well, "and is very accurate, but of no use against iron-clads.

"The Emperor is trying a gun of his invention, rifled, and made of "steel inside, and brass outside. I have no faith in it.

"It is from the United States that we expect the production of the "large rifled gun for sea-service, as soon as your clever workmen "shall have turned their minds to the production of built-up guns of "steel or wrought-iron.

"That heavy gun is much wanted, since the battle of Mobile has so "much shaken the confidence in the employment of rams."

The following significant paragraph appeared in the papers, curiously enough, the following morning. It forms part of Mr. Adams' letter to Earl Russell on the claims against the "Alabama," &c.

"Further than this, I might only suggest to your Lordship to con- "sider which of the nations of the world presents in every sea around

"the globe the most tempting prizes, in an event no friend would "more deplore than myself, of its being again as it has so often been "heretofore, doomed to be afflicted by the calamities of a war."

The practical lesson to be derived from these considerations seems to me to be, in the first place, that our nation depending so largely for its means of existence and prosperity, on the supplies derived from abroad should establish as rapidly as possible a defensive naval force in every colony capable of maintaining one, according to the provisions of an Act of Parliament passed in April last, "to make better Provision for the Naval Defence of the Colonies," a title indeed, which in itself admits the necessity for what I am endeavouring to recommend, although it is little likely to be carried into full effect so long as a semblance of defence from home is maintained.

Secondly: reserve a sufficient number of our existing iron-clads for home defence, rendering them in all respects as efficient as possible for that specific purpose, and adding to their number a great many turret ships, almost confining our future iron-clads to that form of armament; and

Thirdly, to enlarge the idea of "improved Alabamas," as the class of small corvettes now in course of construction has been too truly termed, in favour of vessels in every respect equal, and in point of numbers far superior to the magnificent class of ships constructed in America, giving them if possible central armament in shot-proof cupolas such as have been adopted in the Italian turret-ship "l'Affondatore."

The existing engines of our line-of-battle ships might possibly be made available for propelling such ships at a very high speed.* Their wooden hulls could be quickly put together, as evidenced in the "Lord Warden," of 4,000 tons, partially armoured in course of building, which was laid down in November or December, and launched the following August.

Give them steel frames, beams, and decks, and they would be still more quickly constructed and infinitely stronger and more durable.

Such ships would not only protect our vital interests in distant seas, but would maintain the honour of our flag against all enemies whatsoever.

They would moreover, in time of peace, restore the declining spirit of seamanship in our navy, and being armed with but a small number of the heaviest guns, these might always be maintained of the best and most approved description.

To imitate the Americans still further, instead of retaining these particular ships on certain stations, spending the greater part of their time in the hurtful inactivity of foreign ports or at the various head-quarters of the different admirals' commands, let their cruize extend to every sea in turn where an admiral's flag is kept flying.

* Our line-of-battle ships and frigates have a proportion of length to breadth as 4·5, or 5 to 1, while we have seen that the Americans build on a ratio of 7 to 1. This change of proportion, with the improved form of a rectangular midship section and very fine extremities, would enable the same engines to propel at a much greater speed.—W. H.

By this means each station would be provided at all times with a certain number of fast ships for any special occasion which might arise, while the ships themselves would come in turn under the command and inspection of every Commander-in-Chief.

A greater uniformity of system would thence ensue among both admirals and ships; certain specified rendezvous at particular times would keep the movements of the ships sufficiently under the control of Government, and ensure communication throughout the fleet.

The cruize of each such ship round the world, when not detained by special emergency, would be her period of commission. Its duration could be perfectly controlled by the several admirals under whose command she passed, while the functions of the admirals themselves, in taking care that every place of importance should be duly visited from time to time, would partake more of independent reality and less of the system of centralisation which, for good or for evil (and it is much to be feared that the latter condition predominates), has been in a manner forced upon every branch of the Administration through the enlarged use of the telegraph and the increased facility of communication which have arisen in the last ten or twelve years.* I may mention two circumstances in illustration of this tendency to centralize, as bearing immediately on the subject in hand.

About the year 1858, application was made by some of the Australian Governments to purchase, at a fancy price, some of the old teak block-ships fitted with screws for coast defence.

Most of the ships have since been otherwise disposed of; but the offer was then refused, as tending to separate the colonies from the Imperial Government.

In the year 1865, however, we find a Bill passed, entitled "The Colonial Naval Defence Act," giving power for colonies to provide vessels and raise men, and to commission officers, &c., the clauses of which Act may shortly be stated as follows:—

1st. Power for colonies to provide vessels and raise men and commission officers, &c.

2nd. Volunteers to form part of Royal Naval Reserve.

3rd. Power to Admiralty to issue special commissions.

4th. Placing of colonial vessel with men and officers at Her Majesty's disposal.

5th. As to services of volunteers and officers in navy.

6th. Delegation of Admiralty powers to naval officer.

7th. Not to impose charge on imperial revenues, &c.

8th. Not to affect powers vested in colonies.

I have been unable to learn in what degree it is contemplated to carry the provisions of that Act of Parliament into effect, beyond enrolment of volunteers for the Royal Naval Reserve, with a view to their employment in the Royal Navy, thus drawing a supply of seamen from the very source for the protection of which the Bill is enacted.

* It would also be a great improvement if on all foreign stations our ships were kept in more constant movement under sail, instead of remaining, as occasionally they do, for many months together in the same port, producing many inconveniences both to individuals, to discipline, and to the public service in other respects.—W. H.

For all other purposes this Act appears consigned to the same limbo with the vote for the establishment of Naval Barracks, and in which lay for many years, the Act for establishment of Naval Prisons.

The other measure to which I referred was the abolition of the Indian Navy—a small force, but efficient for the purposes required of it, and comprising a body of officers familiar with those seas in which, as a result of experience, the ships were well adapted to serve.

These two measures on the part of Her Majesty's Government, which it would be scarcely becoming on my part further to discuss, nevertheless bear strongly on the question of separate Colonial Defence, which intimately affects both the services and the distribution of our ships, and consequently the nature of the ships themselves.

Let the full purpose of the Colonial Defence Act be carried into effect, establish dockyards in the distant colonies, with suitable, and well-protected depôts of coal, and let the colonies maintain and begin to use them, in preparation for their separate existence in time to come, and thereby provide for the refit and repair of the ships of the Royal Navy in case of an extended naval war. It can hardly be said with truth that the colonies are attached to the mother country by such questions as affect the declining days of worn-out block-ships, nor, in the present day, would a warlike conflict with the mother country be the manner in which their separation should be effected; but the transfer of some of the colonies to other hands might well arise in time of war, out of their present defenceless state.

It happened on more than one occasion (so at least according to the newspaper account), that small cruizers of the Northern or Southern States during the late war, arrived in ports where no power existed able to compel their departure at the expiration of the allotted time.

The colonies should at least be made capable of resisting such casual cruizers without delay; and, by degrees, be rendered so independent as to leave our ships available for their own definite use as cruizing ships of war.

Let the ships constructed to cruize upon the high seas be of a character to maintain the honour of our flag against all enemies; for this purpose let them be in all respects at least equal, individually, to any possible enemies, while numerically more powerful; and lastly, though we may hope and trust that the United States of America may not again stand in that relation to us, let us remember that heretofore we suffered more at their hands than by all other enemies combined against us, and considering them the most formidable foe with whom we may be brought into conflict, let us construct on the principle and pattern of theirs, a far larger number of similarly serviceable ships than they are likely to require or to possess.

The adoption of such a type and class of ships would not be without an incidental consequence which is professionally of the very first importance.

Together with a revival of seamanship we should obtain a considerable increase in the number of *bonâ fide* seamen.

The idea has taken hold of many minds, and I confess to having myself shared the opinion, that the introduction of iron-clad ships would

very much reduce our navy, restricting the necessary number of both officers and men, and confining within comparatively narrow limits the much-to-be-desired force which is expressed by anticipation in the term "Standing Navy."

Rightly or wrongly, the Government appears to have adopted that view of the case, and has acted upon it in all but the final object to which a reduction of number would especially have seemed to direct, and, limiting the theory of a permanent naval establishment to the existing system of engaging the men for ten years, and of supplying boys through the training-ships exclusively, a great prominence has been given to the two elements of reserve, viz., the body of 7,000 men in the Coast Guard, and whatever number may be forthcoming, when required, from among those enrolled in the Royal Naval Reserve.

The present system of manning the navy, as must be known to most persons present, is a very excellent one *as a theory* (but one which, I think I shall show, requires to be much extended in practice), viz., that of receiving scarcely any men, and those under peculiar circumstances, otherwise than by the advancement of boys as they grow up, who begin their career in the training-ships between the ages of $14\frac{1}{2}$ and 16 years.

Such boys undergo an excellent preparation in ships devoted to that use, under the command of officers, especially selected on account of their qualifications. The navy affords so good an opening for respectable lads, that any number of them could be obtained from rural districts, brought up in the parish schools or workhouses, strong and healthy. Instead of which I shall presently show that only a sufficient number of boys are allowed to pass through the training-ships to supply one-half of the annual waste.

Leaving aside the quality of the article, and dealing only with the numerical part of the question, about 2,000 boys pass annually through the training-ships, to supply an annual deficiency of between 4,000 and 5,000 men, discharged from various causes, including disease and death.

This numerical loss, though becoming less in proportion every year, is nevertheless continued year by year through the pursuance of a system which, during the past ten years, has diminished the number of seamen—I speak of actual sailors—in Her Majesty's Navy, by no fewer than 20,000 men. Now, although this loss of men is said to be compensated by the two-fold Reserve of Coast Guard and enrolled men from the merchant service and elsewhere, it could not be continued without very great inconvenience, were the navy more actively employed than it is at present.

Not many years since, a reserve of seamen was kept in hand at each of the naval ports, in readiness to embark on any emergency.

By this means the great delay in manning newly commissioned ships was avoided, and the system being still in force when the affair of the "Trent" arose, ships were despatched in a very short time, through the zealous exertions of the officers in command (*e. g.*, the "Orlando," 50-gun frigate put to sea in six days from the appointment of her Captain, Francis Scott, C.B.), whereby great credit accrued to the naval administration for its activity and forethought.

Should a similar emergency arise at this time, I believe the Coast Guard would have to be embarked, for want of any available reserve in the ports.

Should the Royal Naval Reserve be required, it is supposed that about 8,000 men could be at once found available.

Still, neither the Coast Guard—good men though they be—nor the various qualities of men who receive £6 a-year for passing through a periodical training in the use of guns and arms, would supply the deficiency of real active seamen.

It is true that the *quondam* seamen, who have entirely abandoned the sea and followed other trades, are being eliminated from the Reserve as fast as practicable, and their place supplied by men more or less accustomed to the sea, and able to satisfy the official authorities who receive them into the Reserve, that they actually possess a stipulated amount of seaman-like skill. Nevertheless, the qualifications of an able seaman in the merchant service are wholly undefined by law, and many more such men are required to supply the ready activity and the skilful qualities of a far smaller number of disciplined seamen, trained from their youth upwards in the Royal Navy.

Information from various sources shows that the greatly increasing demand for seamen in various quarters of the globe—which has truly been said to have "*grown larger*" within the last few years—will continue more and more to drain our merchant service of men, whom the proffered advantages of the Reserve will scarcely suffice to retain available for the sudden service that may be required of them. I believe it to be a common practice at Liverpool for emigrant ships to evade the law which requires them to carry a crew numerically greater than those of ships otherwise employed, by inserting the names of emigrants on the ships' papers instead of the additional seamen, the persons thus inscribed signing the articles of agreement, and receiving pay at the rate of 6*d.* or 1*s.* per month.

The provisions of the Act of Parliament, if not thus evaded, would demand about 3,000 seamen annually, who would be discharged on arrival at their port of destination, and of whom the majority would enter upon some more profitable vocation.

The reduction in the number of available seamen from these and other causes has led to evasion of the law in the manner described, through the difficulty in obtaining them.

An official return from the Registrar-General of Seamen, completed to 1863, showed that during the previous five years, while the *ships*, the *tonnage* and the total number of *men* in the merchant service had increased respectively as 4, 9, and 4 per cent., the absolute *decrease* in the sailor class during the same period had been as follows:—

Petty Officers	600
Seamen	200
Apprentices and boys	3,000

Making a total of 3,800 sailors lost to

the country out of the merchant service alone in 5 years, being at the rate of 65 per month.

This loss of seamen, added to that which occurs in the Royal Navy, is a very serious matter in a country whose existence may be truly said to depend on the sea which surrounds it.

The increased number of ships during those five years demanded an increase of crew to the amount of 4 per cent., while the tonnage increased in the same period 9 per cent. This increase was chiefly in steamers, for we find the increase of the men to consist of 600 engineers and 1,700 firemen.

Among the sailors, however, we find another kind of increase upon which we cannot congratulate ourselves as a maritime nation, viz., that of foreign seamen added to the merchant service to the amount of 7,500 in the same five years, which represents a daily entry of *four* foreigners against a daily loss of *two* British seamen.

On mentioning this fact to a merchant ship-master of great experience, I was met by the reply that he preferred Swedes, Norwegians, and other foreigners, to many of the British seamen obtainable by merchant ships in the present day.

Another experienced ship-master observed to me on the same subject, "the navy was formerly glad to get what men it could; but now "it has all the best men, and we are obliged to put up with what we "can get."

Surely if this be the character of the supply on which we depend for our Reserve, it is not only important that an abundance of seamen should be trained expressly for the navy, of whom many would join the Reserve after the completion of their term of engagement in the navy; but also that we should employ them afloat in such ships as would keep them in the constant exercise of seaman-like qualities, by which alone can their superiority be maintained.

I will read a passage from a letter addressed to His Grace the Duke of Somerset as First Lord of the Admiralty, by the present Controller-General of the Coast Guard, and by one of the members now representing Liverpool in Parliament, who is also chairman of the Local Marine Board at that port.

Those gentlemen viewed the loss of nautical skill from this country in so serious a light, that they published their letter as "On the national "dangers which result from the great deterioration in the seamen of "the mercantile marine."

The writers evidently gave much consideration to the subject, and must have been deeply impressed with its importance, if we may judge by the amount of pains they bestowed on the elaboration of their letter.

Indeed, to find considerations of national honour on the sea, to say nothing of national security at home, made subordinate to the fiscal questions of the day, but little encourages any attempts to press upon public consideration the importance of recruiting our naval force from the condition into which it has settled down, and is still, year by year, settling lower.

Commodore Ryder and Mr. Graves, in their pamphlet, dwell upon

the necessity for seamen to possess certain qualities which they describe as follows:—

"(1.) *A firm footing* in all weathers, at all times, by day or by night, "aloft or in boats, which is essential to accurate practice with great "guns or small arms.

"(2.) That *bodily activity* which results from constant exercise *aloft* "in all weathers.

"These two qualities combined make our seamen fearless and irre- "sistible boarders. Whatever may be the improvement in artillery, or "the progress made in the art of rendering a ship's sides invulnerable, "boarding will always remain as a last resource to decide otherwise in- "conclusive actions at sea and cutting-out expeditions in harbour; and "boarders, to do their work effectually, *must* have that agility which "on board ship or in boats can alone be found in sailors.

"(3.) That readiness of resource which is largely developed in Eng- "lish lads who love and follow the sea, and enables them when they "become men to contend with and overcome difficulties afloat or on "shore, and to anticipate or repair accidents with a surprising "rapidity.

"These three qualities, when combined with that tenacity of purpose "common to all Englishmen, make up the distinctive character of true "English sailors, whose presence in large numbers in our future naval "actions cannot be dispensed with if we desire to insure victory."

I may have appeared to some of my hearers to be digressing from the subject announced at the head of my paper. I must, if so, reply that I feel very strongly that one principal merit in the establishment of a class of ocean cruizers, to be actively employed in all parts of the world, would be its effect as an antidote to the listless life engendered among men shut up in iron-clads, so constructed as scarcely to be trusted to move from one port to another without the aid of steam.

If such, then, be the state of affairs with the seamen in the present day, neither are our younger officers trained in such seaman-like habits as was formerly the case.

Not only, in cant phrase, is the "schoolmaster abroad," but he now reigns supreme *on board*, in his demand upon the time of the young gentlemen under his tuition.

The ships are very few and far between in which lads have any opportunity of becoming thorough seamen, and the consequence is such a low standard in that respect, that I have heard a lieutenant speak of a youngster in commendatory terms, adding, as a kind of make-weight, "and he is very fairly up in his *sailorising*."

Then, owing to the paucity of lieutenants, these same lads, who are examined and passed with reference to their opportunities of instruction and practice, become in their turn lieutenants in all the responsibility of that rank, without ever being properly "*up in their sailorising*." I heard of a large ship in the Channel squadron being tacked at night in a manner to cause the captain to remark upon it afterwards to the officer in charge of the watch, and it turned out that he had never in his life put a ship about until required to do so at night, when keeping station in company with other ships.

Now, this is scarcely the state of things we can desire to see in the British Navy, and one great remedy for it, in my humble judgment, would be the employment of such ocean cruizers as I have endeavoured to recommend.

We are approaching to the state of the Spanish Navy, when it possessed, as was said, more admirals than seamen, for we have already more flag officers on the various lists than we have midshipmen. I refer to the Navy List for the numbers, and I find upwards of 320 officers bearing the title of admiral, as against 104 in the rank of sub-lieutenant, besides those who may be acting in that rank, and from amongst whom many are doing the duty of lieutenant.

The lieutenants, I find, are 20 per cent. below their established number, and it is from the trifling number of sub-lieutenants that the deficiency has to be made up.

Give us active cruizers, again I say, to restore a seaman-like spirit, skill, and activity among both officers and men. It is not yet too late, but who shall tell when it may be! and when the time of trial comes, little will it avail to seek remedial measures.

The classes of ships recently constructed in America would give employment to real seamen, some of whom being always in reserve in naval barracks, would be at hand to form a nucleus for manning with the Coast Guard and Naval Reserve those iron-clad ships destined to form the squadrons for home defence on any emergency.

If the colonies maintained a sufficient naval force for protection of their coasts—which it is nothing but an impossibility for this country even to *attempt* to do for them—then the number of ocean cruizers might be reduced in time of peace, and a reserve of such ships maintained in readiness at home, could, in event of war, be fitted out by degrees as the enrolled seamen returned from abroad, at the estimated rate of 1,000 a-month, besides which, we may count for something the enthusiasm displayed, by the Northern seamen especially, at the time of the "Trent" difficulty.

It needs little argument before a professional meeting of this description, to establish the superiority of copper-bottomed ships for lengthened service in distant seas, over those of steel or iron.

In a lecture delivered at this Institution by Commr. F. Warren, on 20th March last, the annual expense of docking and varnishing the bottom of an iron ship of 3,700 tons, is stated as £677 2*s.* 8*d.*, while the increased expenditure of steam-fuel consequent upon the foulness of such a bottom, so prepared, after less than six months' service, amounts to more than 25 per cent.

Considering the cost of coal on distant stations where this increased expense may be supposed to arise, this increase amounts to a very large sum upon even our iron troop ships alone.

In the "Megæra," for instance, whose best speed is 10 knots, her progress, whether under steam or sail, was impeded 1·5 knots per hour after only three months' service, and double that amount after six months.

Apart from the decrease of efficiency for general service, and large increase of expense, we have to consider the positive risk of losing a

ship, under circumstances where this loss of motive power, whether expressed in speed or fuel, added to possible unmanageableness in consequence, might tell most fatally.

It appears, therefore, a *sine quâ non* that ships for lengthened and distant and foreign service—and especially in time of war—should be free from the many objections which must ever attach to an iron bottom.

No substitute of any real merit among the many contrivances tried or suggested, appears likely to supply the good qualities of the old copper bottom.

An iron clipper ship has been very successfully coppered by Messrs. Austin, of which the details have appeared in the public papers.

I have been told by a friend of the owners, who have patented their method of sheathing, that although no other shipowners have been induced to follow in their footsteps—probably deterred by a question of royalty on the patent—yet they (Messrs. Austin) have been remunerated for the expense incurred, by the two first voyages of their ship, whose displacement and consequent carrying power have been so largely increased.

Of course the ratio of displacement to propelling power has to be considered in constructing a ship on this principle of a wooden sheathing outside an iron bottom. But this is a trifling problem in the hands of a constructor.

The bottom of the ship has been tested by the removal of portions of the sheathing, and in all those places, as I am informed, the insulation of the iron has been so complete as to have perfectly protected it against the destructive effects of the copper.

Finally, then, let these ships with steel frames, inside skins, wood-planking,* and coppered bottoms, be provided with iron masts of great strength, and of large diameter, to withstand the effects of shot; let those masts be, as far as possible, independent of their lower rigging for support, by being built into and forming part of the ship; give them cap topsails and long mastheads, and I believe they would combine the qualities required for long cruizes, beyond any other description of vessel yet produced. Fit them either with twin screws or else with feathering single ones, and balanced rudders, arm them with a few of the heaviest guns upon whose soundness you can rely, with some howitzers in addition for use at close quarters; let them carry, perhaps, an iron belt above and below the water-line, but certainly an iron inner skin, and divide their holds into water-tight compartments, and they may go forth in confidence to seek in vain for their superiors and to find their equals if they can. Such ships will, at the same time, increase the efficiency of the navy in quality of material, while also keeping alive the spirit of true seamanship among both officers and men.

To resume shortly the purport of the present paper.

I desire to advocate especially three great principles, namely, the

* On the Clyde, these union-built ships are constructed with diagonal planking in two thicknesses crossing at right angles, *planed*; they cost less than £18 per ton. This would be too cheap for the Royal Dockyards.—W. H.

adaptation of particular ships for particular duties; that the ships of each class should be as nearly as possible consimilar: and that *speed*, with an armament of large calibre should be the principle pervading all classes of ocean-cruizing ships.

Secondly, I would urge the importance of constructing, without a moment's loss of time, as many as the country will consent to grant, of ships on the pattern of the large American corvettes.

Thirdly, that such ships should be the means and the occasion of keeping on foot a greater number of *bonâ-fide* seamen in the Royal Navy, whose expense could well afford to be deducted from that of the Royal Naval Reserve.

Such men would be of too great value to be inconsiderately cast aside at the price of one farthing or less in the pound, of income-tax, and the Coast Guard should be maintained on an *increased* footing for their reception, not only for the sake of keeping on hand a Reserve very superior to that of the mercantile marine, but above all for the avoidance of that baleful evil which has so often arisen out of Parliamentary parsimony, namely, the want of good faith towards our seamen.

The more active employment of our officers would not only be a boon to them, but such employment as the class of ships which I have endeavoured to recommend would afford them, would prove an antidote to the prejudicial effect which the use of steam, in ships fitted out beforehand, has had upon the practical seamanship of almost every class in Her Majesty's Navy, as well as in the mercantile marine.

Nor these points only, but in event of war, we should be in a suitable position at sea to resist the depredations upon our commerce and our colonies, which will, in future conflicts with other countries, occupy the place of the great naval actions that adorn the history of Great Britain.

APPENDIX.

A List of the Iron-clad Naval Force of European Nations other than Great Britain and France.

Taken from "Statesman's Year Book" for 1866, *and from other sources.*

Italy.

		Guns.	H-p.
4 Frigates	each	36	900
7 „	„	26	700
2 Corvettes	„	20	400
2 „	„	12	300
2 Gun-boats	„	5	150
1 Cupola ship	„	2	700
18 ships		402	10,900

In addition to the above, the sanction of Parliament has been obtained for the construction of 4 other iron-clads.—*Quarterly Review*, October, 1865.

Russia.

2 Frigates.
22 Corvettes.
1 Clipper.
3 Batteries.
11 Coated gun-boats.
14 Plated batteries.

53

Austria.

		Guns.	H-p.
2 Frigates	each	32	800
3 „	„	31	650
2 „	„	28	500
Total 7		213	4,550

Prussia (Scheme).

	Guns.
10 Frigates	250
10 Turret ships	40
8 Corvettes	224
6 „	93
Total 34	607

Spain (Scheme).

	Guns.	H-p.
3 Frigates	104	3000

By decree of April, 1860.

Denmark.

4 Iron-clads.

Netherlands.

Unknown.

Turkey.

9 Iron-clads.

N.B.—Different States in South America are also providing iron-clad ships of war.

Admiral HALSTED: I would merely observe, upon the statement regarding the number of guns in our iron-clads as compared with the number in the French iron-clads, that Captain Horton has included all our guns, as if they were all under armour. I do not think he has made the distinction between armoured and unarmoured guns.

Captain HORTON: They are the guns carried by armour-clad ships.

Admiral HALSTED: In the case you quote, of the "Black Prince" and the "Warrior," instead of 41 guns under armour, they have only 26. I see the "Defence" and the "Resistance" are put down in the list for 16 guns: it should be 14, they have only 7 broadside guns under armour. The "Achilles" has only got 11 under armour, double broadside 22. If you take this point into consideration, you will see that we are much worse off, as compared with the French, than you have represented. What I am stating is rather an addition to your unfavourable comparison. I would merely add, that I fully agree in all the general remarks you have made. But when you say your wooden ships have an inch skin of iron, they are in truth ships of iron, and not of wood; in which case they may stand the effects of the machinery, which is necessary to give them high speed; but ships of wood could not sustain those effects. I do not believe we possess a single armed ship of wood which could really and truly put forth her powers of high speed, up to anything like 2,000 horses and upwards for any continuous period in time of war. There is no such thing in existence as a screw-ship at the present moment in the merchant service built of wood, as the result of *bonâ-fide* experience. They have all gone to pieces; and ours in the Navy would go to pieces too if they were really put to proof. But the fact is, we do not, in time of peace, continue running them in the way, in which they would be required to run in time of war. However, your proposed combination of an outside skin of wood, and an inside skin of iron might answer. I did not understand whether your frame was proposed to be inside or outside that skin of iron. To do any good, it should be inside in order to support the skin. Then, again, how are you going to apply your wood? I believe the Americans themselves would build of iron, and would armour their iron ships as we are doing, in most cases, but they have a great excess of wood and very little experience in the construction of iron.

The CHAIRMAN: How would you dispose of the difficulty of the bottom?

Admiral HALSTED: I do not believe that it is a difficulty, for this reason; I never accept anything as difficult where sufficient means have not been tried to get over it. Its existence at the present moment can be got over in the case proposed by Captain Warren; again, in the case proposed by you; again, as proposed by Mr. Grantham; and so far back as the lectures which I delivered here in 1861, showing precisely the same evils, a national effort was suggested. It has long become a national question, involving a national effort to get over it. I have noted here a remark of Captain Horton, that the system of fouling is inevitable with iron bottoms. But if I understand him aright, he immediately afterwards quoted vessels of Messrs. Austin—I think that was the name—where the fouling had been got over.

Captain HORTON: I beg your pardon; one ship has an iron bottom, and the other has a copper bottom exposed to the water, no matter what she has inside.

Admiral HALSTED: I do not quite apprehend the difference which you have made. At any rate it is perfectly certain that there has never been any national effort made to get over the very great evil which you have described. The special talent of the country, qualified to meet a difficulty of that sort, has never been appealed to. It would be worth while to expend any number of tens of thousands of pounds of the public money, for the purpose of really constituting a committee of the ablest men to take up the question nationally. Up to the present moment, it has been left in the hands of individuals, who have been excited by their individual interests to attempt it. But there has never been anything like a connected system, or attempt made of a public nature, to get over it. Let me revert to a circumstance which occurred many years ago, when screw-ships were first introduced, and when the projection of the screw shaft under water was the then means for connecting and disconnecting. The screw shaft projected beyond the stern-post, and was exposed to the action of the copper. At that time it was found that Muntz's metal was the material which was least

productive of the galvanic current; and so far back as the days of the "Amphion," in 1846 and 1847, it was proposed to make all the stern portions of the ship, including the stern-posts and the rudder, of Muntz's metal. Ships at that time were ordered to be sheathed with Muntz's metal, on account of its materially decreased effect as a galvanic power. The ship I commanded was so sheathed. The object is so important, that there is no reason why Muntz's metal itself, thick plates of Muntz's metal, should not be substituted for iron plates. To give you an idea that such a thing has been practically contemplated, I may say that not many years ago, it was made the subject of a patent. Upon an estimate it would have cost for a ship of the size of the "Warrior" about £30,000 more, to have constructed all her lower parts and her outside plating entirely of Muntz's metal. I do not at all believe that there is any permanent difficulty about the business. I never admit that difficulties do exist to this great extent, unless they have been fairly, and to an equal extent, attacked by those who are competent to deal with them. I give you great credit for the way in which you have drawn up your paper. I believe you have done a great public service by so doing, and I am very happy to state my opinions thus publicly upon the matter.

Captain HOSEASON, R.N.: It is with much pleasure that I rise to say how much gratified I am with the paper just read. I cannot say that I agree with Captain Horton in every particular, but as a whole I have listened with much pleasure to every word that he has read. Captain Horton has dwelt upon the importance of speed; but there is a view of this question which has seldom been taken by the majority of the profession. We all know that the horse-power required, is as the cube of the velocity. To enable me to illustrate this, I will take simple figures. I will take 10; the cube of 10 is 1,000, and the cube of 8 is 512, or about one-half the cube of 10. It is thus seen that to pass from 8 knots to 10 knots requires double the horse-power. All parties admit this, but few think of the reverse. If a gale of wind drives the speed of a vessel down from 10 knots to 8 knots, practical experiments over thousands of miles, as well as theory, tell us that the vessel thus reduced from 10 to 8 will maintain an average of about 8 knots, while the vessel with a maximum speed of only 8 knots will, in the same proportion, be driven down to nothing. I do not know whether I have made myself clearly understood? (Yes.) You will thus observe the importance of obtaining the average speed of a vessel as shown by her runs in the open ocean, subject to heavy seas and winds, and not be content with any comparison obtained at the measured mile in smooth water. Admiral Halsted has alluded to the fouling of the bottom in iron vessels. That becomes an ingredient in the speed, for when that foulness takes place, the advantage derived from a higher power is effectually destroyed. When I was in the East Indies, Captain Potts came out from England in command of the "Malta," a fine new iron steamer, belonging to the Peninsular and Oriental Company. He, like every sailor, was in love with his own ship, and stated the high average speed that his steamer had maintained from Singapore to Hong Kong. I believe the speed stated was 12 knots an hour. I had always reported the "Inflexible" to be a slow boat, considerably underpowered and undermasted. The Admiral asked me if I could "beat that." "Oh, no," I replied; "if the 'Malta' has averaged that speed, the 'Inflexible' cannot beat her." We had a trial of speed, however, before the "Inflexible" left the station, in a run from Hong Kong to Singapore, and thence on to Bombay, against the south-west monsoon. You must bear in mind the advantage the "Malta" possessed in having every arrangement made for immediate coaling on her arrival in port. I had to land, and to make every arrangement subsequent to my arrival. Nevertheless, I beat her eight days on the run to Bombay. The advantage I gained over her was two days in the smooth water between Hong Kong and Singapore. It was the foulness of her bottom alone, I believe, that enabled me to beat her to that extent, as was shown when she went into dock at Bombay. On the other hand, when the "Inflexible" was taken into dock, after having been in commission eighteen months, and just after making a run of 9,000 miles from New Zealand, her bottom was perfectly clean. It is important to state that three vessels ran in this race—the "Malta," the "Inflexible," and the "Fury." All started within a few hours of each other, and encountered the same weather.

Both the wooden vessels beat the iron vessel in this decided manner. The "Inflexible" had an advantage over the "Fury" in this portion of the run of half a mile an hour. The latter did not go beyond Singapore. Now, in the construction of these magnificent vessels, which are said to cost from £250,000 to near £400,000, I think there ought to be some more experimental trial than the measured mile in England. They ought to be tried over given distances in the open ocean, where alone the true average speed can be obtained. Some of the large iron-clad steamers on Captain Horton's list appear to have a very low rate of speed. If this is the result of their trials at the measured mile they will most likely fail to make even a mile of headway when encountering adverse winds, and a heavy head sea. I read lately in a daily paper that an official in the French Marine had reported that some iron-clad vessels lately launched had suffered so much from corrosion, that he anticipated they would require to be replated every five years. I cannot say if this statement be true or false. It is, however, no argument against the construction of these monstrous vessels. We must have them so long as other nations have them. At the same time let us build vessels such as are proposed by Captain Horton, that will do the duty which the "Alabama" did—paralyse the whole commerce of the enemy, and protect our own. I entirely agree with Captain Horton that each class ought to have a speciality. Vessels of certain classes ought to be built for certain specified objects, and it ought to be clearly established by experiments obtained over given distances in the open ocean, that they can fulfil every condition of the class for which they are intended. Our imports and exports last year were 444 millions, and this year will be close upon 500 millions; and, certainly, we ought to have something to protect those vast commercial interests. (Hear, hear.) We are fully in a position to protect our own coasts, but let the Administration say, if war were to break out to-morrow, whether we should be able to protect our vast mercantile marine from the attacks of an enemy.

Mr. A. F. RIDGWAY: There is one point which Captain Horton touched upon which I think of vast importance, and that is in regard to our colonial defences. There is only one of the colonies which, as yet, has attempted to have a navy, and that in a very small way—the colony of Victoria. There was a ship built here, and sent out to that colony a few years ago. The gentleman who has just sat down spoke of New Zealand. In New Zealand the necessities of the war have called up the energies of the colony in ship-building, and in manufacturing steam-ships. I am very glad to see by the papers which arrived recently that a vessel built for mercantile purposes, named the "Tasmanian Maid," bought by the Local Government, and christened the "Sand Fly" and other vessels that were employed in the service of the Government in the late operations have been well supplied with coal raised in the colony. There have been immense discoveries of coal in New Zealand, so that ships employed by our Government out in those colonies could be well supplied with coal. Then, there are very large deposits of iron-sand all along the coast, which parties are now setting to work to bring into the shape of iron; so there is no lack of iron to build ships of war. There are a great number of places on the coast where ship-building can be carried on extensively. A great many shipwrights from Newcastle-upon-Tyne and the northern ports have gone to New Zealand, and the building of ships is becoming a considerable trade. The vessels that run into Sydney and Auckland are several of them of large size.

Captain JASPER SELWYN, R.N.: I think, Mr. Chairman, I must claim a few minutes to speak on one or two principles which Captain Horton has so very ably put before us. His paper has been so comprehensive that I think every one will agree with me that it deserves a longer discussion than time will permit. However, it is necessary that we should look at this formidable array of a foreign navy in all the lights, if possible, to which it may be subjected. I confess that in his beautifully arranged list of French vessels of 900 horse-power all through, and of 16 guns, I see something which reminds me of that dead level of mediocrity which is generally the result of a settled plan closely stuck to. Whereas in this country, although we have committed very great errors in armoured ships, and I have been among the very first to admit it and to point it out, yet we are going forward; while the French appear to have limited themselves to a type which they conceived, and which they

are prepared to defend, as being perfection. When I remember that a ship which I do not see in the list, the "Hercules," has advanced to nine inches of armour, and with a probable speed of not less than that of those which now carry the very inefficient thickness of four and a half inches, I think we may say that we have made an enormous advance, and one for which uniformity may very well be sacrificed. If we can go forward in that direction, if we can obtain a still further advance in the use of steel for the hull, which gives us the power of carrying so great a weight of armour without unduly diminishing the speed or the other qualities of the ship, I think we are bound to do so. If, again, we only consider the difficulties of the galvanic problem, which has not yet been attacked as well as it might have been, but which is in process of solution, we shall find that much remains to be done before we reach the limits of the advances that we ought to make. I see one Officer of the Royal Navy present who has attacked this problem with a large measure of success; and I know several other inventors who do now practically prevent fouling and the decay of the iron. They do it by the adoption of a two-fold principle. Where you desire to prevent fouling there must be a slow decay of the surface; and where you desire to prevent decay of the bottom, some other material, the application of a pigment to the outside, must be resorted to. In these two things the necessary conditions will be obtained. The bottom will not decay, because you have arrested the action of the galvanic current; and fouling will not take place, because you have provided against it by a process which will prevent the adhesion of grass and barnacles. The answer to the proposition for the establishment of an un-armoured class of vessels may be found in the fact that we possess already such an un-armoured class of vessels. If we desire them, we have a merchant navy which we could arm with such few guns as may be necessary, and which we could employ satisfactorily without pretermitting any of the advances which we are making in iron-clad vessels, which are an inevitable necessity where fleets are to act against fleets. It would be very unsatisfactory to an officer of the British Navy if, finding himself in command of an unarmoured vessel, he was opposed to one of those wretched little armoured tubs, which it would not consort with his dignity to run away from, and which he would fight at an enormous disadvantage. (Hear, hear.) The question of changing ships which Captain Horton has spoken of is one which he may not have remembered would introduce much more of that undesirable material, foolscap, which has come into the navy in such floods of late years. I doubt very much whether any set of Admirals could keep their brains under the strain which would be thrown upon them by the constant change of ships, officers, and everything else connected with their command. I do not agree with Captain Horton's views about the turrets. I believe these turrets are excellent things in their place; but that they will compete eventually with broadside armoured vessels I do not believe, for this reason, amongst others, that although a very good show is made when turret-ships are only pleased to fight one side, and all their guns are pointed on that side against a single enemy, yet when it comes to a fight with both broadsides that is quite another affair. Then the weight of metal thrown is by no means equal to that that would be thrown by a broadside armour-ship. Also, because in the necessity of the case, the ship requires to be armoured as well as the turret; therefore, you are devoting one special armour to the guns, and another special armour to the hull. We might have cause to take a gloomy view if we were once to admit that the superiority of the French and American navies was so far established as these figures tend to show. In the case of the French navy, I think, we should have cause for doubt and distrust; and with regard to the American navy, we should recollect that they, like ourselves during the Crimean War, built a very large number of vessels for the special purposes of their war which would not be of the slightest importance as against us; and that the question of the "Alabama" and her consorts reduces itself to this—that any nation, not possessing any navy whatever, never having had a navy previously, the Chilians at this moment possessing three or four ships only, may, by sending one fast cruiser to sea, whose mission is not to be caught, but to catch the commerce of the enemy, send up the rates of insurance in the country against which the attack is made, and her flag disappears from the sea. It is not because all the ships belonging to the country attacked will be caught by that vessel, but it is because any of the

ships may be caught by that vessel, therefore the rates of insurance go up; and it is felt better not to send your own ships to sea, but to put your cargo under the flag of another nation. With regard to the twin-screw system and turrets, I must also beg to remark that in this Institution two of its distinguished members have been respectively the consistent advocates for some years past of these two things; but I do not think it a compliment to them that their efforts should be taken hold of by a department of the State, without acknowledgment of any sort, be called by another but slightly altered name, and brought forward as the unaided efforts of the genius of that department. I hope the country is of opinion that whenever a man has proved his point fairly, after the very great discouragement which all inventors meet with in this country in their first efforts, that he does then deserve to be publicly recognised, and not to have his efforts stolen from him, or abstracted from him in any sort of way. I hope that what we say in this Institution will be so far re-echoed as to convince those gentlemen who have the management of these affairs that their best policy is to seek for and openly praise that talent which they may often find by applying to the members of the sister services for their ideas on points in which such men are most experienced, and in which some among them have shown special knowledge, and have taken special interest.

Mr. E. J. Reed, Chief Constructor of the Navy: I am not quite aware of the exact purport or intention of the last remarks of Captain Selwyn, but I quite concur in the principle that when you can trace an invention to an individual inventor it is a duty to reward that inventor. Captain Selwyn's remarks have very much taken away the ground upon which I was about to stand for one or two moments in speaking of Captain Horton's paper. It seems to me not at all likely to influence public action wisely when comparisons between the navies of this and other countries are introduced on an unfair basis, or a basis which we should not recognise as a sufficient basis for comparison, when dissimilarities in vessels, dissimilarities in power, dissimilarities in armament, and dissimilarities in tonnage are adduced as necessary disadvantages. Captain Selwyn has already pointed out that the uniformity in the French navy points to something like mediocrity. I think we are scarcely furnished with the funds necessary to pursue uniform systems with the improvements which are continually taking place in guns and ships. I am not at all prepared to say that the full amount of desirable uniformity exists in our ships, but I do say that some of the greatest dissimilarities that exist between them are due to justifiable causes. I will instance one or two cases. Among the list of first-rate ships on the wall we find there are ships which are dissimilar only because a recent change has not come under the notice of Captain Horton. I think the "Northumberland" will have a less number of protected guns than the other two vessels of her class. Now, why will that vessel have a different number of guns? For this reason, that the ship has been a long time in building, while armour plating has increased in thickness, and guns have increased in power, and it was deemed advisable to avail ourselves of the backward state of that ship to place upon her thicker armour, and an increased calibre of guns in her battery. Now, I can hardly imagine any officer of the navy censuring a change of that kind, unless it involved an objectionable principle in construction. I merely say that the discrepancy that will exist between the thickness of armour of that ship and of other ships of her class, and the difference between the armament of that ship and of other ships of her class, can hardly be made a ground of complaint. I hardly think we should be in a better position if we had adhered to the ideas which prevailed at the time she was begun to be built. More than that, I am disposed to think that, when vessels with a very large increase in the thickness of their armour, and a very large increase in the power of their guns, are brought against vessels with smaller guns and less armour, as in the French navy, that they will produce the same consternation as an armour-plated ship would originally have produced among a fleet of non-armoured vessels. It appears to me that it would be deplorable if the weight of an Institution like this should be given to impede the efforts made by responsible persons to increase the power and efficiency of our ships. Again, I may point to the circumstance that mentioning the nominal horse-power does not point to a considerable discrepancy of speed or power. I will illustrate that remark in this way: In the case of the "Lord Clyde," which you find

of the same nominal horse-power as the "Prince Consort" and the "Caledonia," her engines are upon a new principle which developes a larger power than the engines of other ships. What is the consequence of that? That by virtue of that increase in effective power, though of the same nominal power, that ship is enabled to carry five and a half inches of armour at her water line instead of four and a half, and an extra inch and a half over her gun deck; her armour also extends further beneath the water, she has higher ports, and it is supposed she has other advantages in comparison with other ships of the same nominal power. Now, I submit whether any one would be prepared to maintain that the "Lord Clyde" is a worse ship because she has a different type of engine, which enables us to give her increased weight of armour and increased weight of guns—worse for no other reason than that if you compare her with other vessels of the same nominal horse-power she differs from them in armour and guns. Again, with regard to the armour of the French ships, it is perfectly evident that if the efforts made in this Institution and other places to improve the power of guns, which is more or less associated with the increase of weight of guns,—if these efforts are right there is only one way of utilising the ships you have, that is, by putting into them guns of increased power with a less number of them. Ships are things that you cannot put guns of twenty tons in place of guns of ten tons into, and have the same number of them. I think it is hardly a fair ground of censure that you have been putting ten guns in one ship in place of twenty in another, when you have been increasing the power of that ship by putting in guns of larger calibre. Then, I think it is unfair to say that the French navy is a superior navy to our own. While they have ships uniformly armed with guns that fire a low charge of powder, we are arming other ships with guns that fire 50-lb. charges of powder. I consider the uniformity is a uniformity of mediocrity, a thing not at all to be desired; and I think we may congratulate ourselves upon the fact, that in this country we have been enabled to increase the power of our ships, even if with some disregard to mere uniformity of figures. I should like to make another remark which is only fair to the navy; that is, that those ships given on the board are not so dissimilar as represented. The "Caledonia," the "Ocean," the "Prince Consort," the "Royal Alfred," and the "Royal Oak," are all built from precisely the same designs. The three ships, "Caledonia," "Prince Consort," and "Ocean," are as much alike as three ships can possibly be. They differ from the others in the amount of their power; and recently the "Royal Alfred" has been made different from her consort by the substitution of thicker armour and larger guns. But those three ships which have precisely the same power are to all intents and purposes alike. Everybody knows the "Warrior" and "Black Prince" are substantially alike; and if there is any discrepancy in their armament, it is only because you cannot, with the improvements that are going forward, produce the new guns so quickly as to put them into every ship. Some remark has been made about our ships not being adapted to work in squadrons. In a letter which I wrote to the *Times* newspaper two or three years ago, I showed that there are a large number of these ships perfectly capable of working in squadrons. But vessels built alike often differ much from each other. The "Scorpion" and "Wivern" appear to be exactly alike. They are the two turret vessels supposed to have been built for the Confederates by Messrs. Laird; those vessels are built from the same designs, yet the "Scorpion" and the "Wivern" differ half a knot in speed. Everything is alike in other respects. I have not with me the speeds of all those vessels mentioned, but if you were to group them you could put them in speeds differing not more than from half a knot to a knot. It would be useless to think of improving the speed of our ships if a difference of a knot or half a knot is to be considered an insuperable objection to the working of our ships in squadrons in time of war. There was another remark made by Captain Horton. He has discussed the question as if we had no ships at all capable of crossing the seas and disposing of such powerful vessels as might be sent against our navy. I fully agree with Captain Horton and the other gentlemen who have admitted—and people are obliged not only to admit, but to feel with great pain sometimes—that the iron ships are subject to more or less diminution *of speed*; but any one knowing those vessels must be aware that ships like the "Warrior," the "Black Prince," and all

those larger vessels are just as capable of making a voyage across the ocean, and of doing, in fact, all that the un-armoured vessels could do, as any vessels which we might possibly build. I do not say this in depreciation of Captain Horton's main points, because I am very much impressed with the desirability of building everything in advance of what has been done before. It seems to me a legitimate use of the wealth of this country to learn what other people are doing, and then, if possible, to make everything in advance of them. I shall not, perhaps, be exceeding what is allowable under the circumstances if I mention what Captain Horton has not been at liberty to mention, namely, that the construction of a class of vessels, such as he has been projecting, has been seriously entertained. But, unfortunately, there are great difficulties in the way. You know perfectly well that it is not an easy thing to build a vessel to steam 15 knots. One of the American vessels mentioned this evening by Captain Horton has been put forward by the builder as capable of 15 knots. The American Government, however, do not believe in her. They have undertaken to pay the builder in full for the vessel if she will make 12 knots an hour; and they have, moreover, undertaken to pay him in proportion to the cube of the speed between 12 and 15 knots, so little confidence have they in the statement. There is one general consideration which ought not to be lost sight of,—that neither the French ships nor the American ships have engines equal to the engines in English ships. The American engines are much heavier than ours; and it is chiefly on paper in this country that they steam their vessels at very high speeds. We could do the same if we chose. I think no dependence can be placed upon figures on paper as to the speed of their vessels. It should be borne in mind that every ship built by the Admiralty is subjected to the severest trial of speed on the measured mile, which I agree is not and ought not to be a final trial. But it is a desirable trial, because it gives you comparative capabilities. I should have been glad if those vessels in the French navy which are said to steam at a speed superior to ours could have had a race with some of our vessels at the international meeting at Portsmouth, the "Magenta" with the "Warrior," for instance. My own opinion is, that the French vessels do not equal ours in speed; yet, on the other hand, I must say that I believe the deficiency in speed would in many instances be compensated by the extreme handiness which the shorter vessel has. However, I do not think it fair to lose sight of the fact that these general representations are exaggerated with regard to the speed of vessels of other nations; and that the American vessels have yet to do the extraordinary speeds of which we have heard so much. I hope my remarks will be taken in the spirit in which they are made, in the spirit in which this Institution promotes the discussion of these questions. I am sure that Captain Horton will feel that in making them I have no desire to detract from the main value of his paper. On the contrary, I am very glad to find that officers of his ability and experience do contribute their views on these important matters. But I think naval officers would do extremely well, if they wish their words and facts to have weight with the State, to take pains to analyse their facts and figures, and give us a basis for everything they say, on which we can proceed practically.

Captain HORTON: I am obliged to Mr. Reed and other gentlemen for such concurrence as they have expressed in the views I put forward, especially as my object is to advocate the preparation, which Mr. Reed has kindly informed us is under consideration, of un-armoured ships. They may fail as much as the American ships have failed; still, what I wish is, that the attempt should be made to produce a class of ships competent to cope with those which are prepared in America with a definite object, namely, the destruction of our commerce. We, on the other hand, should be capable of protecting our commerce against such depredators as they might turn out. The commerce of this country with our colonies, on the high seas constitutes one of our weak points. With regard to the figures I have put on the board, I stated in my paper that I was under correction; that they were put there for the purpose of comparison; but I cannot vouch for their accuracy. Mr. Reed has the advantage of knowing facts which are foreign to me. I have merely taken them from such documents as I can find. The French ships I have illustrated in that table possess an uniformity, from which they appear to have a great advantage in squadron sailing, of which our ships see so little in the present day. It is satisfactory to learn that a

many of our ships are so nearly alike. I have counted the varieties which do exist among them, and I find there are eleven classes in respect of guns, ten classes of horse-power, and nine classes of tonnage. Among those there may yet be great uniformity; and if Mr. Reed will kindly indicate to me those which form the same kind of squadron, it may be of great interest and value to the meeting.

Mr. REED: The first six would go together in point of speed, down to the "Black Prince."

Captain HORTON: Did you not mention four of the wooden vessels?

Mr. REED: The "Caledonia," the "Lord Clyde," the "Lord Warden," the "Prince Consort," the "Ocean," those five; and several others might be named.

Captain HORTON: Then we may congratulate ourselves upon having two squadrons of powerful ships. The stronger they are the better. I am not an advocate for mediocrity, but for improvement, though not simply for single vessels being improved in their good qualities, but also for those of inferior quality being improved up to a better standard. With regard to my idea of the "Union" form of building, they are ships composed of steel frames. Inner skins also, wood planking, steel beams, and steel decks would be a great protection to our crews. Captain Selwyn mentioned the possibility of fitting out merchant ships. Ever since the Peninsular and Oriental Company was founded, and the West India Mail Packet Company was formed, it was one of the conditions imposed upon them that their ships should be capable of carrying guns. But, surely, those are not ships that would be sent forth on a long cruize to contend with the American ships of which I spoke. I do not advocate wooden ships or any particular form of ships, but simply a general principle. But I think the transfer of the commerce of this country from our own to a foreign flag would be about the most miserable condition of things this country could ever witness; not only unfortunate for our position as a nation, but it almost implies starvation. We should hardly get things from our enemies—supposing we were at war with America; and had to rely upon foreign flags—unless it were that our own ships were transferred to foreign flags, and I think we should be scarcely well off in that case. Mr. Ridgeway favoured us with information that the colony of Victoria is setting an example, which I hope will be quickly followed by other colonies, that of forming a navy. That is a question of state upon which I merely touched. With the professional topic of ships I am more capable of dealing. I do not know that there are any other objections raised which require a particular reply. We are told that certain things are in progress, as also certain measures for protecting ship's bottoms against corrosive decay and against fouling. We do not possess these things at present; but we do know that copper sheets do protect ship's bottoms against fouling, and I think we should avail ourselves as far as possible of things existing rather than of those in prospect.

The CHAIRMAN: I would take this opportunity of relieving Mr. Reed's mind by stating that this Institution is not embarked in any desire to foster or forward any wrong opinions. It is distinctly stated on the outside of the journal that the writer of every paper is responsible for his own opinions. The members of the Institution are not at all committed to them. The writer states his own opinions here, and then they are open to be objected to by anybody. Everybody is entitled to take objections. This regulation is made in the hope that discussion will be brought about. We sometimes like to see an adverse paper, although the generality of us may not be favourably inclined to the views contained in it, for the very purpose of elucidating what is the truth. I confess I think Mr. Reed is very hard on the writer of the paper, inasmuch as I did not understand the object of it was to set forth the superiority of the French, but merely to advocate one simple principle. He was not contrasting ship with ship, and saying that the English ships were inferior to the French, but that in them there was system, design, which it was desirable to have, for ships acting in squadrons. Mr. Reed must be very sensible that, in case of accident, to have a number of ships in squadrons and all these ships with different kinds of engines, and different in their construction in every way, is, of course, a disadvantage. I only understood Captain Horton as taking that view—(Captain HORTON: Simply)—as desiring to have a fixed pattern; not at all advocating mediocrity, but progress; and that as a main feature—for that in reality was the main object of his paper—advocating that class of

vessel that he enlarged upon, which the Americans are building, and which Mr. Reed admits is now in course of construction, thus recognising the principle. Captain Horton dwelt upon that, and Mr. Reed admitted it. I do not know that anybody here except Captain Selwyn spoke of the introduction of steam-packets.

Captain SELWYN: Not steam-packets; vessels fitted for such a purpose.

The CHAIRMAN: To take the ordinary packet-ships from their regular service I think would be a very great injury, not only to trade, but to the postal arrangements of the country.

Captain SELWYN: Pardon me; I said that in our merchant navy, not confining it to the great Steam-packet Companies, or any particular class of vessels; there are such vessels to be had if you advertise for them.

Captain HOSEASON: May I allude to what you have said about these ships? I happened to be out in India when a secret order came from the Government to the Peninsular and Oriental Company to arm their vessels. I was the only naval officer there, and I found the greatest possible difficulty in making those ships available at all.

The CHAIRMAN then proposed the customary vote of thanks to Captain Horton for his paper.

LECTURE.

Friday, January 19th, 1866.

CAPTAIN E. GARDINER FISHBOURNE, R.N., C.B., in the Chair.

THE NEW SCIENCE OF DUAL ARITHMETIC APPLIED TO NAVAL AND MILITARY CALCULATIONS.

By OLIVER BYRNE, Esq., formerly Professor of Mathematics, Civil Engineers' College, Putney.

GENTLEMEN,—A scientific lecture could only interest or entertain a highly enlightened and experienced audience like the greater portion of the one that I have the honour to address, either by bringing to their minds subjects long forgotten, or by offering materials for thought upon matters engaging their immediate attention; and but for the newness and importance of my subject, it would be my first duty to apologise for entering upon the principia of this or any scientific subject, however profound. Then, without further introduction, allow me to say that

Dual arithmetic is a new art of manœuvring numbers and investigating the relations of quantities with ease and accuracy, with or without the use of tables. In the most general sense dual arithmetic is a new art, and not merely a new method of obtaining results that might be found by arts previously known. The science of dual arithmetic unfolds the capabilities of numbers in an original manner, extends the boundaries of mathematical science, and establishes new rules, by which many difficult problems of the greatest utility and importance are solved with ease, without the aid of tables, cumbersome formulæ, or methods of approximation previously resorted to.

The term *dual* is employed because the art has *two branches*, the bases of each branch being composed of *two parts*, but, chiefly because the digits of a dual number may be subjected to a variety of changes in magnitude and position, while at the same time constantly equal in value to *two unchangeable* extremes, namely, a natural number and a logarithm to a known base.

In combination the system is threefold:—

Natural Number | Dual Number | Dual Logarithm.

Since the digits of a dual number are susceptible of a vast variety of changes without altering its two ultimate values, dual numbers may be said to be changeable without being variable.

Numbers in the dual system of arithmetic are expressed by the continued product of the powers of one or more of the bases which are seldom introduced into the figurative operations of the art. However, the powers and products are always obtainable by common addition and subtraction.

↓ *Bases of the ascending branch.* ↓

$$+\infty \ldots\ (10000+1);\ (1000+1);\ (100+1)\ (10+1);\ (1+1);\ (\tfrac{1}{10}+1);\ (\tfrac{1}{100}+1);\ (\tfrac{1}{1000}+1);\ \ldots\ldots\ 1;$$

more conveniently written

$$+\infty \ldots\ 10001;\ 1001;\ 101;\ 11;\ 2;\ 1{\cdot}1;\ 1{\cdot}01;\ 1{\cdot}001;\ 1{\cdot}0001;\ \ldots\ 1,$$

increasing in magnitude from right to left.

These bases are less and less as they approach 1, but cannot be less than 1.

↑ *Bases of the descending branch.* ↑

$$-\infty \ldots\ (1-10000);\ 1-1000);\ (1-100);\ (1-10);\ (1-1);\ (1-\tfrac{1}{10});\ (1-\tfrac{1}{100});\ (1-\tfrac{1}{1000});\ \ldots\ldots\ 1;$$

but more correctly written

$$-\infty \ldots\ -9999;\ -999;\ -99;\ -9;\ 0;\ {\cdot}9;\ {\cdot}99;\ {\cdot}999..1.$$

This scale of bases approaches 1, but cannot be greater than 1.

A single example will make clear anything that may seem too abstract in these general statements.

In order to avoid the common but faulty practice of illustrating by small pet numbers, let us take the supposed diameter of the earth through the poles, which is said to be 7898·8809 statute miles of 5280· feet each; therefore, the diameter = 41706091·152 feet, which, according to usage, is a contracted method of expressing

$$4\times(10)^7+1\times(10)^6+7\times(10)^5+6\times(10)^3+9\times(10)^1+1+(10)^{-1}+5(10)^{-2}+2(10)^{-3}.$$

In common arithmetic the coefficients 4, 1, 7, &c., are termed digits, and do not exceed 9. In dual arithmetic the powers of the bases are only registered; they are also called digits, but they may vastly exceed 9. Thus 41706091·152 is equal to

$$(1-{\cdot}1^5)^3(1-{\cdot}1^6)^2(1-{\cdot}1^7)^5(1-{\cdot}1^8)^6(1-{\cdot}1^9)^9(1-{\cdot}1^{10})^1(1+1)^2(1+{\cdot}1^2)^4(1+{\cdot}1^3)^2$$

when multiplied by 10000000.

The bases being omitted, this dual number is written

$$41706091{\cdot}152$$
$$\parallel$$
$$'0'0'0'0'3'2'5'8'9'1 \;\; 7\downarrow^{2} \;\; 0,4,2,0,0,0,0,0,0,0,$$
$$=$$
$$'3'2'5'8'9'1 \;\; 7\downarrow^{2}_{5} \;\; 4,2,$$
$$=$$
$$7\downarrow^{2} \;\; 0,4,1,9,6,6,9,5,6,4,$$
$$=$$
$$'8'3'1'4'8'7'3'4'3'4 \;\uparrow^{3}$$

and equal to thousands of other dual numbers, each expressed by a different set of dual digits, but every one reducible to the same dual logarithm 1754615775,.

In an extended form 41706091·152 is equal to

$'0'0'0'0'3'2'5'8'9'1 \uparrow (10)^{7}(2)^{2} \downarrow 0,4,2,0,0,0,0,0,0,0,$ more conveniently written $'3'2'5'8'9'1 \; 7\downarrow^{2}_{5} \; 4,2,$

'3'2'5 &c., are called dual digits, and express the powers of the bases involved. The positions are reckoned from left to right before ↑ representing the descending branch, and from left to right after ↓ representing the ascending branch. The powers of 1·1 occupy the first position after ↓; the powers 1·01, the second position after ↓, and so on. The powers of ·9 the first position before↑; the powers of ·99 occupies the second position before ↑; and so on. According to this conventional arrangement, '3 in the fifth position before ↑ represents $(\cdot 99999)^{3}$, 0, in the first position after ↓ indicates that no power 1·1 is involved, and in general ciphers are employed to indicate that no power of the corresponding bases are involved.

The position of a dual digit before, between, or after the signs ↑ and ↓ points out its value.

$$n\uparrow^{p}m \qquad m\downarrow^{p}n$$

A small figure placed at p designates the position occupied by a dual digit, and sometimes points out the leading position occupied by the first of more dual digits than one. m expresses 10^{m} and n expresses 2^{n}.

$$m\downarrow^{p}_{p}n$$

The comma (,) is employed in the operations of dual arithmetic, while the period (·) is retained to separate whole numbers from decimal fractions.

General Forms of Dual Numbers of Eight Consecutive Digits.

Ascending branch.

$$m\downarrow n \quad u_1,u_2,u_3,u_4,u_5,u_6,u_7,u_8,$$

Descending branch.

$$,v_1,v_2,v_3,v_4,v_5,v_6,v_7,v_8 \quad n\uparrow m$$

Both branches combined.

$$,v_1,v_2,v_3,v_4,v_5,v_6,v_7,v_8 \quad n\uparrow m \quad u_1,u_2,u_3,u_4,u_5,u_6,u_7,u_8,$$

Nine dual digits give results true to nine places of figures. Ten dual digits give results true to ten places of figures, and so on.

A dual number is easily transformed into another, all of whose digits being reduced to ciphers, except the last. The transformation of a dual number of eight digits into another, whose first seven digits are ciphers, is termed *reducing a dual number to the eight position.*

A dual number reduced to the eighth position is called a dual logarithm.

For example—

$$2. = \downarrow 7,2,6,0,7,8,2,6, = \downarrow 0,0,0,0,0,0,0, 69314718,$$
$$= \downarrow^8 69314718.$$

In practice the 8 is omitted, and the expression is written

$$2. = \downarrow 69314718, \text{ which represents } (1{\cdot}00000001)^{69314718}.$$

Then 69314718, is termed the dual logarithm of $2\cdot$ and written

$$\downarrow,(2\cdot) = 69314718,$$

The dual logarithm of $41706091{\cdot}152$ is equal to the whole number 1754615775, Dual logarithms are always whole numbers.

By very simple means the operator can find any two of the three corresponding numbers :—

Natural number. | Dual number. | Dual logarithm.

The remaining one being given. Indeed in all cases these reductions may be made by common addition and subtraction.

Then, taking for granted that we can make such reductions when required, I now propose to illustrate the power of this new art by applying it to solve some important practical problems, the solution of which would be either impossible, or so laborious, that no one would attempt to perform the operations by arts previously known.

EXAMPLES.

Ex. 1. Find the 7th root of the cube of 41706091·152.

$$\lfloor,(41706901{\cdot}152)$$
$$\|$$
$$'3'2'5'9\ \underset{5,}{7\lfloor^{3}}\ 0,4,2, = 1754615643,$$
$$\frac{1754615775,}{7} \times 3 = 7551978189, \quad = 3\lfloor 6,4,0,3,6,4,2,1,$$
$$3\lfloor 6,4,0,3,6,4,2,1, = 1844{\cdot}165.$$

Ex. 2. Required the common logarithm of 41706091·152 by a direct calculation, or solve the equation

$$10^x = 41706091{\cdot}152,$$

$$\lfloor,(41706091{\cdot}152) = '3'2'5'9\ \underset{5}{7\lfloor^{2}}\ 4,2, = 1754615775,$$
$$\lfloor,(10) = \ \ 7\lfloor,2,3,2,6,7,3,2,0, = 230258509,$$

Then by common division

$$\frac{1754615775}{230258509} = 7{\cdot}62019949.$$

Ex. 3. Required the common number answering to the common logarithm 7·62019949 by a direct calculation,

$$7{\cdot}62019949 \times 230258509 = 1754615775,$$
$$1754615775, = 7\lfloor^{5}, 0,4,1,9,6,6,9,1, = \lfloor,(41706091).$$
$$\therefore\ 7{\cdot}62019949 = \text{the common logarithm of } 41706091.$$

Ex. 4. Given $34{\cdot}56789x^5 - 2345{\cdot}678x^4 - 123{\cdot}4567x^3 + 456{\cdot}7891x^2 + 56789{\cdot}12x = -415978976{\cdot}065$ to find a value of x, true to nine places of decimals.

In my work on the "Art and Science of Dual Arithmetic," it is shown that if $r\lfloor u_1,u_2,u_3, \ldots$ be a root of the equation

$$ax^5 + bx^4 + cx^3 + dx^2 + ex = f,$$

then u_1,u_2,u_3 may be formed from

$$u_1 = \frac{f - f_1}{\dagger 5ar^5 \dagger 4br^4 \dagger 3cr^3 \dagger 2dr^2 \dagger er}.$$

It requires but little observation to see that a value of x lies between 0 and 100, and on a closer inspection it will be found that a value lies between 10 and 30. x may be found conveniently by putting any number from 22 to 12 for r; 20 is selected, because its square, cube, &c., are easily obtained and operated with.

$ar^5 = a_1$ $br^4 = b_1$ $cr^3 = c_1$ $dr^2 = d_1$ $er = e_1$
+ 110617248· − 375308480· − 987653·6 + 182715·64 + 1135782·4

+ 550	5 times	+ 110.....	
− 1500	4 times	− 373.....	
− 950	3 times	−	
	2 times	+	
	1 time	+ 1.....	
		− 264.....	(f_1) take
		− 415.....	(f) from
		−950) − 151	(+ ↓ 1, = ↓u_1,

$a_1\downarrow 5u_1, = a_2$ $b_1\downarrow 4u_1, = b_2$ $c_1\downarrow 3u_1, = c_2$ $d_1\downarrow 2u_1, = d_2$
+ 178150185· − 549489146· − 1314566·942 + 221085·924

$e_1\downarrow u_1, = e_2$
+ 1249360·64

+ 8905	5 times	1781.....	
− 21976	4 times	5494.....	
− 39	3 times	13.....	
+ 4	2 times	2.....	
+ 12	1 time	12.....	
− 1309)		− 3712.....	(f_2) take
		− 4159.....	(f) from
		− 447.....	(+ ↓ 0,3, = u_2,

$a_2\downarrow 5u_2, = a_3$ $b_2\downarrow 4u_2, = b_3$ $c_2\downarrow 3u_2, = c_3$ $d_2\downarrow 2u_2, = d_3$ $e_2\downarrow u_2, = e_3$
+ 206826835· − 619178123· − 1437722·51 + 234687·163 + 1287217·52

+ 103410	5 times	+ 20682.....	
− 247668	4 times	− 61917.....	
− 429	3 times	− 143.....	
+ 46	2 times	+ 23.....	
+ 128	1 time	+ 128.....	
144513)		− 41227.....	(f_3) take
		− 41597.....	(f) from
		− 370	(+ ↓ 0,0,2,3, = + ↓ u_3,u_4,
		− 289	
		81	

The root being thus far determined by contracted operations, let 20 ↓ 1,3,2,5, be substituted for x in the given equation.

The succeeding operation by using the coefficients of the given

equation is independent of those before employed to determine $20\downarrow 1,3,2,5,$. What follows not only determines x to the required degree of accuracy, but also corrects errors, if any be committed.

$$\begin{aligned}
\downarrow,1,3,2,5,0,0,0,0, &= 12766017,\\
\text{square} &= 25532034, = \downarrow,2,6,5,0,0,0,5,0,\\
\text{cube} &= 38298051, = \downarrow,4,0,1,7,4,0,2,9,\\
\text{4th} &= 51064068, = \downarrow,5,3,4,2,4,0,7,9,\\
\text{5th} &= 63830085, = \text{'0'5'4'5'9'2'6'3'}\downarrow 2
\end{aligned}$$

$$\begin{array}{llll}
\text{'0'5'4'5'9'2'6'3}\downarrow 2,^{5} & r^{4}\downarrow 5,3,4,2,4,0,7,9, & r^{3}\downarrow 4,0,1,7,4,0,2,9, & r^{2}\downarrow 2'6'5'0'0'0'5'0,\\
+\ 34{\cdot}56789 & -\ 2345{\cdot}678 & -\ 123{\cdot}4567 & +\ 456{\cdot}7891\\
+\ 209427346{\cdot} & -\ 625398452{\cdot} & -\ 1448541{\cdot}55 & +\ 235863{\cdot}66
\end{array}$$

$$\begin{aligned}
r\downarrow 1,3,2,5,0,0,0,0,\\
+\ 56789{\cdot}12\\
+\ 1290438{\cdot}27
\end{aligned}$$

$$\begin{array}{llll}
+\ 107413 & 5 \text{ times} & +\ 209427346{\cdot} & \\
-\ 250159 & 4 \text{ times} & -\ 625398452{\cdot} & \\
-\ 434 & 3 \text{ times} & -\ 1448541{\cdot}55 & \\
+\ 47 & 2 \text{ times} & +\ 235863{\cdot}66 & \\
+\ 129 & 1 \text{ time} & +\ 1290438{\cdot}2_{7} &
\end{array}$$

$$\begin{array}{lll}
-\ 145704) & -\ 4158\,93344{\cdot}62 & (f_4) \text{ take}\\
\ldots\dagger & -\ 4159\,78976{\cdot}065 & (f) \text{ from}
\end{array}$$

$$\begin{array}{l|l}
- & 85631{\cdot} \quad (+\ {}^{5}\,5,8,7,7, = \downarrow {}^{5}u_5,u_6,u_7,v_5,\\
 & 72852\\
\hline
 & 12779\\
 & 11656\\
\hline
 & 1123^{4}{\cdot}\\
 & 1020\\
\hline
 & 103
\end{array}$$

$$\therefore\ x = 20\downarrow 1,3,2,5,5,8,7,6, = 22{\cdot}7246716$$

Common number. Dual number. Dual logarithm.

$$x = 22{\cdot}7246716\left\{\begin{array}{l}22\downarrow 0,3,2,5,5,8,7,5,\\ 20\downarrow 1,3,2,5,5,8,7,6,\\ 15\downarrow 4,3,4,3,1,1,3,8,\\ 12\downarrow 6,6,6,9,8,4,4,7,\end{array}\right\} = 312345121,$$

&c.

Ex. 5. Find the three sides of a right angled triangle that will have one of its acute angles equal 21° 19′ 37″·8.

The length of an arc of 21° 19′ 37″·8 = ·37222928 radius = 1.
In solving questions similar to this, the operative numbers

1 3 6 10 15 21 28 36 .. ..
and 2 6 12 20 30 42 56 72 .. ..

will be required, as well as the use of the following rules. (See "The Young Dual Arithmetician," pp. 116, 117.)

Rule I.

Set down 10000· times the length of the arc, that measures the least of the acute angles, and divide it by the square root of 2. The quotient will be the dual logarithm of the hypothenuse.

Rule II.

Let h represent the dual logarithm of the hypothenuse, and from the square of h take h; then $h^2 - 3h + 2$; $h^2 - 5h + 6$; $h^2 - 7h + 12$; &c., are found by merely subtracting $2h$ and adding at each step a term of the series 2 6 12 20 . . . .

In what follows $[h^2 - h]$ is put for $h^2 - h$, divided by 10^8;
$[h^2 - 3h + 2]$ is put for $h^2 - 3h + 2$, divided by 10^8,
and so on.

Put A = the length of the arc to radius 1, and B = $[h^2 - h]$;
C = $[h^2 - 3h + 2]$; D = $\frac{B}{6}[h^2 - 5h + 6]$; E = $\frac{C}{10}[h^2 - 7h + 12]$;
F = $\frac{D}{15}[h^2 - 9h + 20]$; &c.

Then A − C + E − G + I − &c., gives the base, and
I − B + D − F + H − &c., gives the perpendicular.

These rules are demonstrated in the author's work on the science of dual arithmetic applied to trigonometry.

$$\text{⌊,(·37222928)}$$
$$\parallel$$
$$\text{'3'⌊}\tfrac{1}{2}\text{⌋,0,2,1,0,8,3,3,0} = \text{'98824528}$$
$$\frac{\text{⌊,(2.)}}{2} \qquad = \text{'34657359}$$
$$\frac{\text{'135481887}}{2} = \text{⌊,(·2632058)}$$
$$\frac{\text{'266963774}}{2} = \text{⌊,(·06927732)}$$

$\therefore$ ⌊,(h) = 2632·058 ⌊,(h^2) = 6927732.

But ⌊,(1·00002632) = 2632,

$\therefore$ Hypothenuse = 1·00002632

$$\begin{aligned} h^2 &= 6927732\cdot \\ h &= \quad 2632\cdot \\ \hline & 6925100\cdot = h^2 - h \\ & \quad 5264\cdot \\ \hline & 6919836\cdot = h^2 - 3h \\ & \quad 5264\cdot \\ \hline & 6914572\cdot = h^2 - 5h \\ & \quad \&c. \qquad \&c. \end{aligned}$$

$$\begin{aligned} \text{Radius} &= 1{\cdot}00000000 + \\ A &= {\cdot}37222928 + \\ B &= {\cdot}06925100 - [h^2 - h] \\ C &= 898589 - [h^2 - 3h + 2]\frac{A}{3} \\ D &= 79808 + [h^2 - 5h + 6]\frac{B}{6} \\ E &= 5930 + [h^2 - 7h + 12]\frac{C}{10} \\ F &= 376 - [h^2 - 9h + 20]\frac{D}{15} \\ G &= 19 - [h^2 - 11h + 30]\frac{E}{21} \\ H &= 1 + [h^2 - 13h + 42]\frac{E}{28} \end{aligned}$$

	Perpendicular.			Base	
A	37222928		Radius	100000000	+
C	1141411	ar. co.	B	13074900	ar. co.
E	5930		D	79808	+
G	181	ar. co.	F	1633	ar. co.
			H	1	+
	·36370250			·93154342	

$\therefore$ Natural sine of 21° 19′ 37″·8 $= \frac{\cdot 36370250}{1{\cdot}00002632} = {\cdot}36369293$

Ex. 6. Required the log. sine, log. cosine, log. tangent, log. cotangent, log. secant and log. cosecant of

21° 19′ 37″·8

$$\begin{aligned} \text{L}(\cdot 36369293) &= \text{'3'0'2'2'}\left|\tfrac{1}{2}\right|,{}^{5}1,0,7,0, = \text{'101141904} \\ \text{L}(\cdot 93154342) &= \text{'1'0'0'4'0'0'5'3}\downarrow,0,3,5, = \text{'7091256} \end{aligned}$$

	'101141904		'101141904	
h	'2632,		7091256,	
	'101144536	= log. sine.	'94050648	= log. tangent.

$$\begin{array}{rl} & '7091256 \\ h & \quad '2632 \\ \hline & '7093888 = \text{log. cosine} \qquad 94050648, = \text{log. cotangent.} \end{array}$$

101144536, = log. cosecant. 7093888, = log. secant.

Ex. 7. Given the equatorial semidiameter of the earth = unity, and the polar semidiameter $= r = \frac{304}{305}$. Required l, the latitude of the central zenith, $l' = 32°\ 29'\ 46''$, the latitude of the apparent zenith, or the spheroidal or geographical latitude being given.

Required also the radius of the place of observation and its logarithm.

Put ρ = radius of place of observation.

RULE.

Take $\frac{1}{3}$ of twice the sine of double either latitude, multiply by 1000· and the dual number ↓ 0,1,6,0,1,0,2,0, the result gives the seconds to be added or substracted.

$$\rho = \sqrt{\frac{\cos l'}{\cos l \cos (l' - l)}}$$

$$\therefore \downarrow,(\rho) = \tfrac{1}{2} \left\{ \downarrow, \frac{\cos l'}{\cos l} - \downarrow,(\cos (l' - l) \right\}$$

$$\begin{array}{rl} \text{Sin } 2\,l' = & \cdot 906\,2\,50\,4 \\ & \qquad\qquad 2 \\ & \overline{3)1\cdot 81\,2\,5\,00\,8} \\ & \overline{60\,4\cdot 1\,66\,9} \qquad \downarrow 0,1,6,0,1,0,2,0, \\ & \quad \overline{6\cdot 0\,41\,7} \\ & \overline{61\,0\,2\,08\,6} \\ & \quad 3\,6\,61\,2 \\ l' - l = 10'\ 14 = & \overline{614''} \qquad \because l = 32°\ 19'\ 32'' \end{array}$$

$$\begin{array}{rl} \cos (l' - l) = & \cdot 99999560 \\ \therefore \downarrow, (\cos (l' - l)) = & \quad '440 \end{array}$$

$$\begin{array}{rl} \cos l = & \cdot 845\,0\,2\,3\,50 \\ \cos l' = & \overline{\cdot 843\,6\,2\,8\,00} \\ & 1\,6\,8\,6\,86 \\ & \quad 84 \\ & \overline{845\,1\,1\,5\,70} \qquad '0'0'0'1'0'9'0'9 \downarrow 0,0,2,0,0,0,0,0, \\ & \quad 9\,2\,20 \qquad\qquad = \\ & \quad 8\,4\,51 \qquad\qquad 188991, \\ & \quad \overline{7\,69} \\ & \quad 7\,61 \\ & \quad \overline{8} \\ & \quad 8 \end{array}$$

$$\tfrac{1}{2}\left[\frac{\cos l'}{\cos l} - \downarrow, \cos (l' - l)\right] = \begin{array}{r} '188991 \\ 440, \\ \hline 2)'188551 \\ \hline \downarrow'94276 \end{array} = \downarrow, (\rho)$$

$$\frac{94276\cdot}{230258509} = \cdot0004095$$

Ar. co. $= 9\cdot9995905 =$ the common log of ρ.

$$\downarrow, (\rho) = '94276 = '1 \overset{5}{\underset{8}{\downarrow}}, 5,7,7,4, = \downarrow, (\cdot99905768)$$

$$\because \rho = \cdot99905768.$$

Ex. 8. Given the apparent altitude of the moon's centre 8° 26′ 13″ (a) the true altitude 9° 20′ 45″ (A), the apparent altitude of a star 35° 40′ (a_1), the true altitude 35° 38′ 49″ (A_1), and the apparent distance 31° 13′ 26″ (d); required the true distance (D), so as to find the longitude at sea.

It is well known that

$$\text{Cos D} = [\cos d + \cos (a + a_1)]\frac{\cos \text{A} \cos \text{A}_1}{\cos a \ \cos a_1} - \cos (\text{A} + \text{A}_1)$$

$\cos d = \cdot8551482$	$\cos \text{A} = \cdot9867261$	$\cos \text{A}_1 = \cdot8126236$
$\cos (a + a_1) = \cdot7180824$	$\cos a = \cdot9891779$	$\cos a_1 = \cdot8124229$
$1\cdot5732306$		

$$\cos (\text{A} + \text{A}_1) = \cdot7071959$$

$$\cos \text{D} = [1\cdot5732306]\frac{\cdot9867261}{\cdot9891779} \times \frac{\cdot8126236}{\cdot8124229} - \cdot7071959$$

·989	17	79	0		
·986	72	61	0	↓ 0,0,2,4,8,2,7,2,	
1	97	34	5	Logarithm	
			9	248172,	
·988	70	05	4		
	3	95	48		
			6		
989	09	60	8		
	8	18	2		
	7	91	3		
		2	69		
		1	98		
			71		
			69		
			2		

·812	62	36	0		
8124	22	90		↓ 0,0,0,2,4,7,0,2,	
1	62	48		Logarithm	
		1		24702,	
8125	8	53	9		
†	3	82	1		
	3	25	0		
		5	71		
		5	69		
			2		

24702,
'248172

'223470 = '0'0'2'2'3'3'7'0 | [1·5732306] = 1·5697188

1·5697188
·7071959

·8625229 = cos 30° 23′ 56″·3, the true distance D.

This number, 41706091·152 Ex. 1 is generally written, scientifically speaking, in the form—

$$4 \times (10)^7 + 1 \times (10)^6 + 7 \times (10)^5 + 6 \times (10)^3 + 9 \times (10)^1 + 1 + 10^{-1} + 5 \times (10)^{-2} + 2 \times (10)^{-3}.$$

I never question the conventional contraction of that great number to 41706091·152. Observe, I omit the fourth and also the second power of (10). In all cases with common arithmetic the power of the base, and also the base, are unrecorded. We merely set down the coefficient, its position before or after the decimal point marks its value. It is readily shown that the dual system of notation is not as compound as the common system.

This system possesses a series of bases, although not employed more frequently than in the old system. I only employ my bases necessary to show what they are.

I will begin with $+ \infty$ and go on to (10,000 + 1): (1,000 + 1): (100 + 1): (10 + 1): (1 + 1). One of these numbers decreased one-tenth; the other remaining stationary, which is 1 — . Proceeding to $(\frac{1}{10} + 1)$, and so on, until it approaches unity, but never becomes so small. These are more conveniently written by the second line.

$$+ \infty \ldots . 10001; 1001; 101; 11; 2; 1{\cdot}1$$

Observe 2 is one of my bases . . . 1 + 1. It would not appear to be so at first view.

This is called the ascending branch, the bases of the ascending branch being positive, and the ⌊ pointing towards a greater number. A comma , and an arrow ⌊ are the only two signs I employ to do all my work. In this place I do not use any other innovation in mathematics.

The other base commences with $- \infty$; and goes on (1 — 10000); (1 — 1000); (1 — 100); (1 — 10); (1 — 1); $(1 - \frac{1}{10})$; $(1 - \frac{1}{100})$; $(1 - \frac{1}{1000})$; . . . . 1.

Observe, 0 is a base of my system, because the bases may be written thus :—

$$- \infty \ldots . - 9999; - 999; - 99; - 9; 0; \cdot 9; \cdot 99; \cdot 999; .. 1$$

It may approach 1, but never arrive to be as great. The old base,

10, has no such power of introducing 0 between positive and negative numbers. Therefore is deficient in range.

The arrow points up ↑ in the descending branch, downwards in the ascending ↓. The powers of 10 and 2 are placed at the centre of the shaft. n is the power of 10, while m is the power of 2. p stands for position.

When ten digits are used the results are true to ten places of figures; when twenty digits are used the results are true to twenty places of figures; when one hundred digits are used the results are three hundred places of figures. The accuracy can be carried as far as you please.

With reference to Example 1, page 38, that is no power of 11; that is in the first position. There is the fourth power of 101, and the square of 1001 in the third position.

The first base. We will say we count from 1 + 1. There is 1 + 10, first, second, and third, and so on. Powers of 1·1 in the first position, powers of 1·01 in the second position, powers of 1·001 in the third position.

So that the position of the digit shows the base that is raised to the power, and the powers are only employed in these cases, not the coefficients as in a common number. In a common number they use the coefficient and not the power of the base. In my system I use the indice only. It is the continued product of the powers of the base that forms the dual number, and not the sum. The dual number may assume a thousand different forms, but it has two ultimate values, the dual logarithm on one side, and the natural number on the other:—

Natural number (dual number) dual logarithm. These two extreme values never change. What I have termed a dual logarithm is a logarithm that is ten times more accurate than one taken from a table of seven figure logarithms. I have, therefore, used eight positions.

This is another form of the same number:—'8'3'1'4'8'7'3'4'3'4 ↑ 8. (See Ex. p. 39).

That is the eighth power of 10. Before the above arrow the counting begins, and after this the digits, '8'3'1'4, &c.

The eighth power of 9, the cube of 99, the first power of 999, the fourth power of 9999, and so on.

These are the descending numbers. Yet very different from the dual number previously mentioned, yet amounting to the same common number, and to the same dual logarithm. The following is another form of the same dual number, all positive, all on the right of the arrow (See Ex. p. 39):—

1↓2 0,4,1,9,6,6,9,5,6,4,

The seventh power of 10, the square of 2, no power of 11, the fourth power of 1·01, the first power of 1·001, so the position of the digits tells the power of the base. It must be again observed, I never use the bases in figurative operations.

This number is called a dual number because the base is composed of two parts; it has two ultimate values that never change. But as a

whole it is threefold, because the dual number is flexible, capable of an infinite variety of forms, and has two values.

If logarithms have to be used, a boy can make them himself. And he can do more than that; he can tell whether Mr. Babbage's logarithms are right or wrong, or Mr. Taylor's, or Mr. Brigg's. I have supplied large tables, which can be looked at when the lecture is over, of dual logarithms for the use of business men, sailors, and those who have to make calculations, but who do not wish to make such calculations for themselves. But there is this difference between the ordinary tables, that any man can tell whether they are right or whether they are wrong. He can check them in fifteen minutes, and can tell whether a dual logarithm, or a dual number, or a sine, cosine, or secant, or anything else, is right or wrong, and in order.

But if this system did nothing more than calculate logarithms, it would be a very useless thing, indeed.

I want to cube that number, 41706091·152, and I want to take the seventh root of the cube. I at once find the dual logarithm of that number; first, the dual number, then the dual logarithm. I multiply the dual logarithm by 3, and divide it by 7, and reduce it back again to its dual number, and then back again to the common number. So that I can take the cube of a number, the seventh root of that, or raise it to any power.

My first example in this synopsis is, how to extract the seventh root of a number, the first problem on page 41.

Find the seventh root of the cube of 41706091·152.

$$\downarrow,(41706091{\cdot}12) = 1754615643,$$

$$\frac{1754615643, \times 7}{3} = 7551978189,$$

$$= \downarrow, (1844{,}165) \text{ the root required.}$$

I require to calculate in a direct way the logarithm of that number, being the second example, or to solve the equation $10^x = 41706091{\cdot}152$ (see Ex. 2, page 41).

Now, in this solution, I do not beg the question. I do not get any number before or behind; I reduce it to a dual number at once, and then to a dual logarithm, I divide that by the dual logarithm of 10, which I also find. The quotient is the common logarithm, by common division.

So that you can take up any number you like, calculate the logarithm from the number itself. This problem was impossible before I discovered dual arithmetic; with the formula generally given for the purpose, it was necessary to dodge from 1 up, and then, by a series of differences, interpolate, either by machinery or other means, the intermediate numbers.

In the third problem, I wish to find the number corresponding to the logarithm. There is no formula to do it, and no one has ever attempted to give one that I am acquainted with. It is very easily done by the dual method, because we have nothing to do but to take the common

logarithm, and multiply it by the dual logarithm of 10, which gives the dual number; bring it to a common number, and the required value is found.

We can test any common logarithm at once, and see whether the logarithm be correct or not. Even the first number given in Baron Von Vega's system of logarithms, the logarithm of the mean distance of the earth from the sun is wrong. For that alone, dual arithmetic requires some little commendation.

In the higher branches of mathematics, its value is shown in such, as finding the area of the curve of probabilities between certain ordinates, and the roots of large equations. The fourth example is an example of the fifth power of the equation, in which the unknown quantity is evolved with very large coefficients. This is the general expression for the fifth power of an equation:—

$$u, = \frac{f - f,}{\dot{1}\,5ar^{5}\dot{1}4bp^{4}\dot{1}3cr^{3}\dot{1}2dr^{2}\dot{1}er}$$

(See page 41.)

The first dual digit must always be equal to that. The denominator of that fraction is something like the differential of the equation, because you can see the powers 5, 4, 3, 2, 1 become coefficients. But the sign there means either *plus* or *minus*, of *plus* more things than 1. We have nothing more to do but to select any number we like between 10 and 30, say 20, 25, 30, and substitute it for the unknown quantity in the original equation. I take 20, and then find out by taking five times the first, of which I put only the first three figures, four times the second, three times the third; I then divide the difference between f and $f1$ by 950, which gives me $\dot{1}1$, — (see Ex. 4, page 41).

But supposing I should make the first digit 2, it does not make any difference; the next would correct it. Then the second digit will be 3 by the same simple process. But suppose I make it 4, 5, or 6, it does not matter, the next step will always correct it. I continue that process, at last come to a stand-still. Now, I do not care whether I am right or wrong, I take one decided step, and I find exactly the value of x to the seventh place of decimals, disregarding whether all that work is right, or whether it is wrong. I take for granted that I have assumed that to be the proper value of x. I square it, cube it, take the fourth and fifth power of it, because we employ the logarithm of the root. I immediately take the original coefficients, substitute these for the original coefficients, and no matter what has been done before this, whether right or wrong in all that has been done, I determine exactly the value of x; and x is shown to be equal to 20 times that dual number.

$$\therefore\ x = 20\dot{1}1,3,2,5,5,8,7,6 = 22{\cdot}7246716.$$

Now, any mathematician that will undertake to find the value of x in that fifth power of the equation by any known process, I need not explain to many here the labour he would have to go through. Sup-

posing I commenced my operations with 22, I should get the dual number, 22⇃0,3,2,5,5,8,5,7. That is the first I commenced with, simply because 2 is easily raised to any power. Had I commenced with 15, I would have got the dual number, 15⇃4,3,4,3.1,1,3,8; had I commenced with 12, I would have got the dual number, 12⇃6,6,6,9.8,4,4,7. I am not limited to what I should begin with. I am sure always to get the same dual logarithm, and the same common value of x to the seventh decimal place.

In my larger work, when I enter into the limits of roots of equation, I show the shortest path. Although I show that the mere tyro cannot go astray, yet I also show how he can save all his time by confining his operations to the narrowest limits. In my works I then show how a dual number may always begin with a digit not higher than 3; that every second dual digit may be an 0; that it is not necessary to do anything but add or subtract, not to multiply by a digit higher than 5.

If it were nothing but finding the roots of these common equations, t would be of some use. But I undertake to solve the equation $x^x = a$, never solved before. I also solve $a^x + b^x = c^x$; an equation that Auguste Comte, in his Philosophy of Mathematics, has stated that to solve this last equation has defied the will of mathematicians, and that it would be impossible to try to solve it.

I shall now go into the more practical part of dual arithmetic.

The CHAIRMAN: Would you explain one or two preliminary stages. Show the change of a natural number into a dual number, and a dual number into a dual logarithm and the reverse.

Mr. BRYNE: Very well. I will put in the first position any digit you like. I will put down the arrow and the digits.

$$\downarrow 3,4,5,7,6,2,5,8,$$

$$\begin{array}{l} \downarrow 3,4,5,7,6,2,5,8, \\ \quad 1\,5\,2\,0\,2\,5\,0 = 3,04,05,0 \times 5 \\ \hline 3\,3\,0\,5\,6\,0\,0\,8 \end{array}$$

The first three digits multiplied by 5, with 0 after each which subtract. I have only two more numbers to operate with to reduce a dual number to a dual logarithm. I will put them down, 31018 and 33.

$$\begin{array}{rl} & 33056008 \\ & 93054 = \text{First digit times } 31018 \\ \text{Second digit times } 33 & = 132 \\ \hline & 33149194 = \end{array}$$

Dual logarithm of ⇃3,4,5,7,6,2,5,8.

That is a dual logarithm. Any schoolboy would acquire the rule in five minutes. The reversing of this process would bring a dual logarithm back to a dual number, a process which never could be done before. It was possible to calculate a logarithm with great labour, but to get a number back again was quite a different matter. I will

put down another dual number, composed of both ascending and descending branches.

	'2'2'7'4'3'2'6'5	↕	3,4,7,6,5,3,6,2,	
Add	1 0 1 0 3 5		1 5 2 0 3 5	Subtract
	2 3 7 5 3 6 1 5		3 3 2 4 5 0 1 2	
36052 × 2 =	7 2 1 0 4		9 3 0 5 4	= 31018 × 3
34 × 2 =	6 8		1 3 2	= 33 × 4
	'2 3 8 2 5 7 8 7		3 3 3 3 8 1 9 8,	

Supposing I wish to reduce a dual number composed of two branches to a dual logarithm at one and the same time, the difference of these numbers have to be taken:

33338198,
'23825787

9512411,

The constants employed for the descending branch are 36052 and 34.

Taking it for granted, therefore, that the operator can convert natural numbers into dual numbers, dual numbers into dual logarithms, and the reverse, it is, indeed, a kind of gymnastics in calculation very easily acquired. He, then, has to recollect that the arrow tells the position in which the first digit stands. Thus ↓[3]3 indicates that the second 3 is in the third position; but as there is no figure on the arrow thus written ↓3, the 3 is in the first position. Had 2'2'7'4'3'2'6'5'↓3,4,7,6,5,3,6,2, been reduced to ↓0,0,0,0,0,0,0,9512411, then let me define what this dual logarithm is; that the dual number corresponding to it would be an 0 in the first position, an 0 in the second, an 0 in the third, an 0 in the fourth, an 0 in the fifth, an 0 in the sixth, and 0 in the seventh position; and the dual logarithm in the eighth position is 9512411, if I put 9512411, in the eighth position, we have a dual logarithm when all the other digits are zeros, which is nothing more than the base 1·00000001 raised to the power 9512411. All dual logarithms are whole numbers; there are no fractions. Therefore, 1·00000001 is the base that I have selected, and is much more correct than logarithms to seven places of figures, and is true to the single digit in the eighth place; altogether true to seven places.

But a common logarithm is this: 10 being the base raised to the power of ·30103 is nearly equal to 2; 10 raised to the power of 0·0103 a decimal, ·30103 called the logarithm of 2. That is the common logarithm of 2. The base of a common logarithm being 10, the power to which 10 is to be raised to produce 2, that power is termed the common logarithm of 2. The hyperbolic system of logarithms are employed in the differential and integral calculus, and is of this sort:—

2·7 18 28 18 28 18 28

raised to the power of $\cdot 69314718 = 2$. It happens that the dual logarithm of a number and the hyperbolic logarithm are made up of the same figures; but one of them is divided by 100000000. So when I have the dual logarithm of a number I have only to cast off 00000000, eight decimals on the right, and I have the hyperbolic logarithm. The dual logarithm, therefore, answers all scientific purposes without any transmutation or change, while it has to be changed in other systems; $(1\cdot 00000001)^{\cdot 69314718} = 2$. If we take $2\cdot 718281828$ for a base it is very awkward. Now, to compare my base with $2\cdot 718281828$. If I require greater accuracy, I take $1\cdot 000000001$, the base beyond $1\cdot 00000001$; if I require greater still I take the base beyond $1\cdot 000000001$. If I want a calculation true to 20 places of figures, I take 10000000000000000001, which you will see explained in my book. But there is no way in which you can change a fixed number like 10, or $2\cdot 718281828$; my base will give it the power of a series of bases, and so the flexibility of a dual number is of great advantage in many ways.

I have taken the Nautical Almanac for 1836, and the plan of calculating longitudes by eclipses or transits. It is necessary first to ascertain the radius of the place where I stand, also the longitude of the place where I stand, together with the latitude of it. In this work the expression for the radius ρ, Ex. 7, page 46. That is $\rho = \left(\frac{\cos l'}{\cos l(\cos l' - 2)}\right)^{\frac{1}{2}}$; $\cos l$ is the cosine of the centre latitude; the other l' is the greater latitude, that given by the line perpendicular to the horizon. Now, to find the value of that expression, I give a simple rule, page 10, which is nothing more than to divide double the cosine by 3; multiply that by 1000· and the dual number ¦0,1,6,0,1,0,2,0, and the result gives the seconds. I need only go as far as 604·, having only used the first and second dual numbers; and I find the number of dual seconds to be 614, consequently the two latitudes differ by 614″. Such a calculation as that is very easily made by dual arithmetic. Now, the cosine of l' is very nearly equal to the cosine of l. The details of the solution of this problem is given at pp. 10, 11. If you observe, the cosine of l' is so very near the cosine of l, you can tell by a few additions and a few subtractions that that is the dual logarithm of the cosine of n, and nearly the cosine of l. I can tell the difference at once between the dual log cosines of these two latitudes.

Sir JOHN HAY: You say a few subtractions. Will you point out the subtractions.

Mr. BYRNE: I have to do something with the number ·84362800 until it becomes equal to ·86502350, Ex. 7. If you observe, I add twice to it in periods of three figures. Thus—

843|628|00
1|686|86

Sir JOHN HAY: You multiply the first three figures.

Mr. BYRNE: Yes, that is by 1, 2, 1, for 2. That number differs from the original number, reference being made to the numbers

·84502350
·84511570

9220 difference

(See page 46.)

Common division gives the remaining numbers, but they are obviously on the descending side. These are all found by subtractions, and only one by addition. That, then, is the dual number, which represents at once a dual logarithm. I do not want to retrace my steps. I would have been approximating towards these results had I to turn back. Now I wish to find the radius of the earth in the proposed latitude. There is the dual logarithm '1885991, page 47, already found. Divide by 2 for the square root. I have reduced my formula into the logarithm of the difference of the cosines. When I have got the cosine I divide that, and find the common number. By dividing the dual number by the logarithm of 10, there is the common logarithm of ρ, see page 47. In one minute I find the common logarithm of ρ, an operation which gives astronomers a great deal of trouble; because I bring the logarithm back to the dual number. The length of

ρ is ·99905768

Supposing it is necessary to obtain this with greater accuracy. It is no matter, if you want a hundred places of figures it is all the same, without employing any extraneous number. Now I take a more extensive number than that. Here is a problem (Example. 8, page 47) that has engaged the attention of naval men for a long time, that of determining the longitude at sea by lunar observations. The solution of this question called the Nautical Almanac into existence, and, I believe, a large book-case might be filled with works on this problem. I will show how to solve it without any logarithm whatever, without a table, without any operation except the operations exhibited in Ex. 8 and Ex. 5.

The CHAIRMAN: The additions and subtractions alluded to are explained in this little book.

The Rev. WALTER MITCHELL: Having been a pupil of Mr. Byrne, I think I know what the gentlemen present wish to have explained. Perhaps it would be interesting to them to see how readily a knowledge of Mr. Byrne's method may be acquired.

There are two branches of Mr. Byrne's art, an ascending and a descending. You may work with either alone, or save a considerable amount of arithmetical computation by combining the two. For the sake of simplicity I shall confine my attention to the ascending branch, and show with what ease any dual number of that branch can be converted into a common number, and conversely, how any common number can be changed into a dual one.

I will write down a dual number—

↓7,2,6,0,7,

The arrow ↓ is a sign that the numbers following it represent a dual

number of the ascending branch, and not a common number. The figures 7,2,6,0, &c., following the arrow, are called dual digits, each digit being separated by a comma, these digits may be any number greater or less than 10. The digits again are said to be in the 1st, 2nd, 3rd, or 4th position, according as they stand in the 1st, 2nd, 3rd, or 4th position to the right of the arrow.

This number ↓ 7,2,6,0,7, is a contracted representation of the continued product.

$$(1{\cdot}1)^7(1{\cdot}01)^2(1{\cdot}001)^6(1{\cdot}0001)^0(1{\cdot}00001)^7$$

The first practical value of the dual arithmetic which we may notice, depends upon the ease with which any number may be multiplied by any of the powers of numbers of the form 1·1, 1·01, 1·001, &c.

Thus, according to our notation,

$$\begin{aligned}
\downarrow 1, &= 1{\cdot}1 &&= 1{\cdot}1 \\
&&&\quad 11 \\
\downarrow 2, &= (1.1)^2 &&= 1{\cdot}21 \\
&&&\quad 121 \\
\downarrow 3, &= (1{\cdot}1)^3 &&= 1{\cdot}331 \\
&&&\quad 1331 \\
\downarrow 4, &= (1{\cdot}1)^4 &&= 1{\cdot}4641 \\
&&&\quad 14641 \\
\downarrow 5, &= (1{\cdot}1)^5 &&= 1{\cdot}61051 \\
&&&\quad 161051 \\
\downarrow 6, &= (1{\cdot}1)^6 &&= 1{\cdot}771561 \\
&&&\quad 1771561 \\
\downarrow 7, &= (1{\cdot}1)^7 &&= 1{\cdot}9487171 \\
&&&\quad 19487171 \\
\downarrow 8, &= (1{\cdot}1)^8 &&= 2{\cdot}14358881 \\
&&&\quad 214358881 \\
\downarrow 9, &= (1{\cdot}1)^9 &&= 2{\cdot}357947691
\end{aligned}$$

In the above example it will be readily seen, that we have obtained the first nine dual digits in the 1st position, or, in other words, the first nine powers of 1·1 by simple addition.

This method of multiplying by dual digits, using simple addition, may be thus generalised. Suppose we multiply the number 3·14159 by ↓ 0,0,1, or the dual digit 1 in the third position, which stands for the number 1·001.

Now by common multiplication—

$$\begin{array}{r} 3{\cdot}14159 \\ 1{\cdot}001 \\ \hline 314159 \\ 314159 \\ \hline 3{\cdot}14473159 \end{array}$$

But this multiplication can easily be performed by addition in two lines, by simply repeating the number to be added, placing its digits in the second line three figures to the right, thus—

$$\begin{array}{r|l} 3{\cdot}14 & 159 \\ & 314159 \\ \hline 3{\cdot}14473159 & \end{array} = 3{\cdot}14159 \times \downarrow 0,0,1$$

This process can easily be expressed in general terms, thus—To multiply any number by a dual digit 1, in any position write the number under itself, placing its digits as many figures to the right as the number of the position of the dual digit. This very easy rule will enable us at once to determine the common number which corresponds to the dual number $\downarrow 7,2,6,0,7$. To avoid needless figures we shall only carry out our result to eight places of decimals, we have already found the value of $\downarrow 7$ to be 1·9487171.

$$\begin{array}{r|l} 1{\cdot}9 & 487171 \\ & 1948717 \\ \hline 1{\cdot}9 & 6820427 \\ & 1968204 \\ \hline 1{\cdot}98 & 788631 \\ & 198789 \\ \hline 1{\cdot}98 & 987420 \\ & 198987 \\ \hline 1{\cdot}99 & 186407 \\ & 199186 \\ \hline 1{\cdot}99 & 385593 \\ & 199386 \\ \hline 1{\cdot}99 & 584979 \\ & 199585 \\ \hline 1{\cdot}99 & 784564 \\ & 199785 \\ 1{\cdot}9998 & 4349 \\ & 2000 \\ \hline \end{array} \begin{array}{l} = \downarrow 7, \\ \\ = \downarrow 7,1, \\ \\ = \downarrow 7,2, \\ \\ = \downarrow 7,2,1, \\ \\ = \downarrow 7,2,2, \\ \\ = \downarrow 7,2,3, \\ \\ = \downarrow 7,2,4, \\ \\ = \downarrow 7,2,5, \\ \\ = \downarrow 7,2,6, \end{array}$$

$$\begin{array}{l|l} 1{\cdot}9998 & 6349 \\ & 2000 \end{array} = \downarrow 7,2,6,0,1,$$

$$\begin{array}{l|l} 1{\cdot}9998 & 8349 \\ & 2000 \end{array} = \downarrow 7,2,6,0,2,$$

$$\begin{array}{l|l} 1{\cdot}9999 & 0349 \\ & 2000 \end{array} = \downarrow 7,2,6,0,3,$$

$$\begin{array}{l|l} 1{\cdot}9999 & 2349 \\ & 2000 \end{array} = \downarrow 7,2,6,0,4,$$

$$\begin{array}{l|l} 1{\cdot}9999 & 4349 \\ & 2000 \end{array} = \downarrow 7,2,6,0,5,$$

$$\begin{array}{l|l} 1{\cdot}9999 & 6349 \\ & 2000 \end{array} = \downarrow 7,2,6,0,6,$$

$$1{\cdot}9999\,8349 = \downarrow 7,2,6,0,7,$$

According to the rules of decimal arithmetic, if we neglect any number in the 9th place, we make the number preceding it greater by one if the neglected digit be greater than 4.

The same method may evidently be extended to a dual number of any number of digits.

It must not be supposed that this is the only or most expeditious method of converting a dual number into a common number, I only use it to show that this conversion can be made by simple addition without assuming any law of binomial coefficients, or any arithmetical process but that of simple addition.

I shall now show, conversely, how to find the dual number corresponding to a common number. Suppose we require the dual number which represents the number 1·12347036.

Referring back to our list of the values of the first nine dual digits, we see that our number must be between ↓ 1, and ↓ 2, or we might make our table till our first two digits corresponded with the number

$$\begin{array}{l|l} 1{\cdot}1 & \\ & 11 \end{array} = \downarrow 1,$$

$$\begin{array}{l|l} 1{\cdot}1 & 11 \\ & 1111 \end{array} = \downarrow 1,1,$$

$$1{\cdot}12211 = \downarrow 1,2,$$

Now, it is evident if we increase the second dual digit by 1, our new number will become too great, we therefore proceed to the third digit:—

$$\begin{array}{l|l} 1{\cdot}12 & 211 \\ & 112211 \end{array}$$

$$1{\cdot}12323211 = \downarrow 1,2,1$$

Any increase of the third digit will make the number too great, we therefore proceed to the fourth and following digits :—

$$
\begin{array}{l|l}
1{\cdot}123 & 23211 \\
 & 11232 \\
\hline
1{\cdot}123 & 34443 \\
 & 11233 \\
\hline
1{\cdot}1234 & 5676 \\
 & 1123 \\
\hline
1{\cdot}12346 & 799 \\
 & 112 \\
\hline
1{\cdot}12346 & 911 \\
 & 112 \\
\hline
1{\cdot}123470 & 23 \\
 & 11 \\
\hline
1{\cdot}1234703 & 4 \\
 & 1 \\
\hline
1{\cdot}1234703 & 5 \\
 & 1 \\
\hline
1{\cdot}12347036 &
\end{array}
$$

$= \lfloor 1,2,1,1,$

$= \lfloor 1,2,1,2,$

$= \lfloor 1,2,1,2,1,$

$= \lfloor 1,2,1,2,1,1,$

$= \lfloor 1,2,1,2,1,2,$

$= \lfloor 1,2,1,2,1,2,1,$

$= \lfloor 1,2,1,2,1,2,1,1,$

$= \lfloor 1,2,1,2,1,2,1,2,$

I have thus shown how any common number can be reduced to a dual number, and conversely how any dual number can be changed into a common number by simple addition. Now, the next thing I propose to do is to convert a dual number into a dual logarithm. Here I may notice a very curious fact. Any common number may be represented by a vast number of dual numbers, each differing from each other as to their digits, but all, when reduced, producing the same common number. For instance, the dual number $\lfloor 7,2,6,0,7,8,2,6,$ may be represented by another dual number, whose first digit is zero, and its third digit some number greater than 70. This may again be reduced to another whose second digit is also zero; and so on we may reduce the original dual number into one whose first seven digits are zero's, and its eighth digit some large number. I cannot detain you by demonstrating the method of this reduction, but shall content myself by stating how it may be done by a simple arithmetical rule. Write the dual number as a common number; add to this the number 31018 multiplied by the first digit, and 33 multiplied by the second digit; subtract from this sum five times the first three digits, each followed by zero, written as a common number.

Thus to find the dual logarithm of the dual number—

$$\begin{array}{rl} \downarrow 7,2,6,0,7,8,2,6 & \\ 2\,1\,7\,1\,2\,6 & = 7\times 31018 \\ 6\,6 & = 2\times 33 \\ \hline 7\,2\,8\,2\,5\,0\,1\,8 & \\ -\,3\,5\,1\,0\,3\,0\,0 & = 702060\times 5 \\ \hline 6\,9\,3\,1\,4\,7\,1\,8 & \end{array}$$

or, $\downarrow 7,2,6,0,7,8,2,6 = \downarrow 0,0,0,0,0,0.0,69314718$

which also means that the number $\left(1+\frac{1}{10^8}\right)$ raised to the power indicated by the whole number 69314718 will produce the common number represented by the dual number $\downarrow 7,2,6,0,7,8,2,6$, which by the method of reduction I have already demonstrated can be shown to be equivalent to the common number 2.

We, therefore, call the number 69314718 the dual logarithm of the number 2.

Now, I think I have succeeded in showing you how the dual logarithm of any common number may be obtained. These dual logarithms possess all the powers and properties of any other logarithms, and are in addition available for operations in which common logarithms would fail. Besides the hyperbolic or Napierian logarithms, and the Briggs' or common logarithms can at once be calculated from them.

To convert a dual logarithm into a hyperbolic one count off eight figures and place a decimal point.

Thus—69314718 is the dual logarithm of 2.

·69314718 is the hyperbolic logarithm of 2.

230258509 is the dual logarithm of 10.

2·30258509 is the hyperbolic logarithm of 10.

To convert a dual logarithm into a common logarithm, that is, one whose base is 10; all we have to do is to divide the dual logarithm by the number 230258509, which is the dual logarithm of 10, which can readily be done by the rule for contracted division by decimals.

If our number be greater than 2 it is evident that our first dual digit will be greater than 7, but if our number be greater than 2 by dividing it by 2, 4, or 8, and some power of 10, we can always reduce it to a number of the form of a decimal whose first digit does not exceed 1, and is followed by the decimal point.

Now, if Professor Byrne had taught nothing more than what I have now shown you that I, as his pupil, can do, and any of you can do for yourselves by the simplest arithmetical processes, he would have a just right to claim the merit of doing what all his predecessors, as mathematical professors, have failed to do, from the days of Napier, Briggs, and Newton, to the present time. But, in addition to this very elementary part of his art, Mr. Byrne has shown you the application of it to the solution of questions of vast importance, hitherto defying the power of the calculator.

Mr. Byrne: I feel very proud of my pupil, and I think he has done it a great deal better than I could do it myself. But had I to stop here,

and could I only have shown you what has been discussed in this lecture I would not have made my appearance here. But I have satisfied myself that, in the five volumes already printed, of which you will find on this table an account, I have framed a system to supersede mathematics as it is by the introduction of a new science called the *Calculus of Form*, out of which the dual calculus has grown. The books which I have in the press will supersede the differential and integral calculus, and clear away fallacies upon which they are based.

The CHAIRMAN: We have had an extraordinary lecture. It evidences extreme boldness if it is untrue, and if it is true, it has extreme ingenuity, when we remember that any extension of the powers of analysis under the old systems, has but increased the difficulty and mystification, for it was no uncommon thing for mathematicians not to be able to read their own answers. Now, this system is really very simple. I have myself gone through a great deal of this little book, and the operations are as simple as those that have been exhibited to you by Mr. Mitchell; in fact some of the process exhibited by Mr. Byrne, and which seemed so very difficult, are merely an application of the simple process explained by Mr. Mitchell. It is a subject so important that it ought to be investigated. (Hear hear). Mr. Byrne has thrown down the gauntlet, and such immense consequences in every department of mathematical science are involved, that the system ought to be fully tested. If any gentleman has any objection to offer, he ought to come forward and substantiate that objection, if not, he ought to admit the system to be correct. It makes mathematical investigations possible to the million. The system is easy to be comprehended by the lowest intelligence; it is just as simple as any of the operations of common arithmetic, and less abstruse and difficult than some. There are a thousand occasions which occur to us when we should like to be independent of the actuary, the mathematician, and the naval architect. We professional men would like to be able to calculate for ourselves, and the fact of our professional knowledge would give us powers of analysis, or means of addressing ourselves to obtain results that we have not now, because mathematicians in looking at things from their own stand-point and not from ours, do not really arrive at the result we want—I mean the practical result. Now, this system will render every man independent of the actuary and the mathematician in every direction. I beg gentlemen not to be dismayed because there is a new system of notation which seems difficult, but which is not really so. But though new it is very simple and definite, and enables you much better to keep in view your chase. A little attention to it, throwing overboard what you have been indoctrinated with to a great extent, and beginning as it were with a blank sheet, you will find it simple, and, as you go on, you will be astonished at the immense power which you will find in your hands. I beg to commend it to this assembly. We have to thank not only Mr. Byrne for the invention of it and for bringing it forward, but also Mr. Mitchell for the very lucid way in which he has illustrated it. We have also to thank

Messrs. Bell and Daldy for the public spirit with which they have taken up this scheme. Without any immediate prospect of results, disregarding vested interests, they have invested a considerable sum of money in its publication. I contend that they are national benefactors. The Council will be anxious to afford every facility for investigation, and no doubt would give a meeting for the purpose, when questions might be asked; and to facilitate the matter some of the questions should be put in writing. Mr. Byrne has been soaring in the highest regions of mathematics until he has got quite transcendental. We unfledged ones must try to bring him down to us till we are able to fly.

Rear-Admiral Sir FREDERICK NICOLSON, Bart., C.B.: Mr. Byrne has stated that his system will supersede the integral and the differential calculus.

The CHAIRMAN: Practically it comes to that, it is more accurate and much more simple in its determinations; and, as he stated to you in one or two cases, which might be multiplied indefinitely, there are equations which cannot be worked out by any other method; therefore, as far as that goes, the other systems are valueless.

Sir FREDERICK NICOLSON: I simply wanted to put a question. As far as I understand the question it is an easier way of solving problems, which have hitherto been solved by the differential and integral calculus. That is as I understood it. At any rate, it is quite a novel proposal in mathematics. Mr. Byrne has given great attention and great labour to it, and has published elaborate books on the subject. The question I was going to ask was simply this, whether these calculations and these books have been submitted to any mathematician of well-known capacity, in order to give a deliberate and an independent opinion on them?

Mr. SCOTT RUSSELL: Perhaps you will allow me to answer that question. I say that Mr. Mitchell is himself one of the highest mathematicians in the land. I believe the subject came before him, not as a pupil, but as a judge; and I believe the consequence of its so coming before him as a judge, was that he entered himself as a pupil.

The Rev. WALTER MITCHELL: I will endeavour to answer Sir F. Nicolson's question. The whole of the dual arithmetic, and all the works now passing through the press, and all the tables, I have looked through myself, and I have not found a faulty demonstration. Every problem is worked out by methods and principles as simple and as easy as anything I have shown you; and that, I think, must be saying something about things which belong to transcendental analysis, and therefore hitherto only to be understood by those who can enter into the highest branches of mathematical science. If this be true, it is something to have the most abstruse speculations the human mind can enter into, reduced to simple addition and subtraction. In Mr. Byrne's book you will find problems solved by the aid of La Place's theorem, and by the aid of La Grange's, and you will find the highest methods of the differential calculus leading you to equations of most difficult solution, and you will be inclined to say, "What a very awkward system this is in obtaining the truth."

Then you have these same problems solved by processes as simple as those I have shown you. But Mr. Byrne goes further, and gets simple solutions of problems where the theorems of La Place and La Grange and all other known methods, utterly fail to give any result.

The CHAIRMAN: Having worked out the results by Mr. Byrne's method, any one can establish by existing means that the answers are perfectly true. I repeat that it is perfectly within the compass of any one here present, to establish that the answers are true. The Council will be glad to give the meeting an opportunity to ask questions.

Adjourned to Wednesday evening, January 24th.

ADJOURNED MEETING.

Wednesday, January 24th, 1866.

REAR-ADMIRAL SIR F. E. NICOLSON, Bart., C.B., in the Chair.

The CHAIRMAN: We are about to resume the discussion of Mr. Byrne's paper, which was read the other day. I believe Mr. Byrne wishes to make some additional statements.

Mr. BYRNE: Viewing this subject from different stand-points, I rapidly passed over one development after another without entering upon minor details. It is very important at starting upon any subject that we start right; therefore, I left it for a separate explanation, and I have taken three examples, the solutions of which are exhibited on the black board. All the figures employed are set down. Although they are common place questions they could not be done without great labour before I discovered this art and science. I have not taken the easiest plan, because that would not bring with it the method of investigating, and you will find that that method of teaching which approaches the method of investigating most nearly is always the best.

The numbers exhibited in the tabulated form I call operative numbers. They are used sometimes as binomial coefficients; they are employed in the calculus of differences; and found useful in calculations respecting the doctrine of chances. This tabulated form is sometimes called the arithmetical triangle. I use it in three different ways. When I employ these numbers in one way in raising a power, it differs materially in the use of them, in passing from step to step, whether positive or negative. Any one can form this table in a minute or so. I set down a line of one's perpendicularly, and one horizontally. I commence with a line of units in a horizontal direction, and another line in a perpendicular direction.

1	1	1	1	1	1	1	1	1	1
1	2	3	4	5	6	7	8	9	
1	3	6	10	15	21	28	36		
1	4	10	20	35	56	84			
1	5	15	35	70	126				
1	6	21	56	84					
1	7	28	84						
1	8	36							
1	9								
1									

I add 1 and 1 = 2; 1 and 2 = 3; 1 and 3 = 4; 1 and 4 = 5; 1 and 5 = 6; and so on.

The third column is made in the same way: 2 and 1 are 3; 3 and 3 are 6; 4 and 6 are 10; 5 and 10 are 15; 6 and 15 are 21; 7 and 21 are 28; 8 and 28 are 36. So, in all cases, I can add diagonally, and obtain the lower corner figure. Again, take these diagonally, 1,2,1, that is the same square of 1 + 1; 1,3,3,1 for the cube of (1 + 1), &c. In the odd cases there are two equal numbers in the centre; in the even one number stands alone. For instance, in the odd number (9) we have 1, 9, 36, 84, 126, 126, 84, 36, 9, 1, and 126 is repeated twice in the centre. In the even number, 1, 8, 28, 56, 70, 56, 28, 8, 1, there is only one number, the 70. So that I might have made half this triangle, and the rest might have been set down without further adding.

If you observe, I can square 11 by adding 11 and 11 together, by passing a figure to the left, thus: $\begin{array}{r} 11 \\ 11 \\ \hline 121 \end{array}$. The cube of it is 1331, found by passsing one figure to the left, thus: $\begin{array}{r} 121 \\ 121 \\ \hline 1331 \end{array}$. The fourth power is obtained in a similar manner, and so on.

Now, these numbers not only find the ninth or any other power of 11, 101, 1001, 10001, 100001, &c., but also the ninth or any other power of 9, 99, 999, 9999, &c. In the second case it is only necessary to make every second operative number negative. I wish to be very particular about these operative numbers; therefore, I will illustrate by an example. Example: Find the eighth power of 9.

$$\begin{array}{r} 1\,\bar{8}\,8\,\bar{6}\,0\,\bar{6}\,8\,\bar{8}\,1 \\ 2\,\bar{5}\,7\,\bar{5}\,2 \\ \hline \cdot 43046721 \end{array}$$

Now I have put down the eighth power of 9 almost instantly without multiplication or continued additions; the second one ($\bar{8}$) being

negative, the third one ($\frac{1}{3}^{\overline{0}}$) negative, then the fifth ($\frac{1}{3}^{\overline{0}}$) negative, &c.

So that I can set down the eighth or any other power of 9. If I had added these operative numbers, I should have had the eighth power of 11, thus, writing the operative numbers diagonally as before:

188606881
25752

2·14558881

Therefore, I can instantly set down either the eighth power or any other of 11 or the eighth or any other power of 9. With the same operative numbers I could set down the eighth power of 101 or 99, 1001 or 999, 100001 or 9999. With these very same numbers, 1, 8, 28, 56, 70, 56, 28, 8, 1,

An example will pointedly exemplify the use of these operative numbers, and give an instance of the great power of this art.

Ex. Find the 7th root of the cube of 41706091·152.

If the dual logarithms of 10 and 2 be not already known, we have to find them. At any time the dual logarithms of these numbers are readily found. Thus,

$$\left|,(2) = \right|,7,2,6,0,7,8,2,6, = 69314718,$$
$$\left|,(10) = 2^3\right|,2,3,2,6,7,3,2,0, = 230258509,$$

$\frac{3}{7}$ root of $2^2 \times 10^7 = 2^{\frac{1}{7}}10^3$.

$$41706091\cdot152 = 10^7 2^3(1\cdot04265228)$$

$$\left.\begin{matrix}\left|^4,\\ \left|^3 2,\end{matrix}\right\} = \begin{array}{r} 104\,265\,228 \\ \hline\hline 104\,060\,401 \\ \quad 208\,121 \\ \quad\quad\quad 104 \\ \hline 104\,268\,626 \\ \cdots\cdot \\ \hline 3398 \\ 3128 \quad '3\uparrow \\ \hline 270 \\ 209 \quad '2\uparrow \\ \hline 61 \\ 52 \quad '5\uparrow \\ \hline 9 \quad '9\uparrow \end{array} \right] \text{Diff.}$$

$$41706091{\cdot}152$$

$$5(0,4,2,) = \begin{array}{r} \text{'0'0'0'0'3'2'5'9} \\ 2\,0\,1\,0 \\ \hline 2\,3\,3\,5\,9, \end{array} \quad \begin{array}{l} \downarrow^{2} \\ \\ \\ \end{array} \quad \begin{array}{r} 0,4,2,0,0,0,0,0, \\ 1\,3\,2 \\ \hline 4\,2\,0\,0\,1\,3\,2 \\ 2\,3\,3\,5\,9 \\ \hline 4\,1\,7\,6\,7\,7\,3, \end{array} = 4(33)$$

$\frac{3}{7}$ of 4176773, $+ \frac{6}{7}$ of $\downarrow,(2) = 61202661, = \downarrow,6,4,0,3,6,4,2,1,$

but $\downarrow 6,4,0,3,6,4,2,1, = 1.844165.$

∴ The 7th root of the cube of 41706091·152 = 1844·165.
4176773, $+ 7\downarrow,(10) + 2\downarrow,(2) = 1754615755$, and

$$\frac{1754615775,}{\downarrow,(10)} = 7{\cdot}62019949$$ the common logarithm of 41706091·152. Again:

$$\frac{1754615775,}{10^{8}} = 17{\cdot}54615775,$$ the hyperbolic logarithm of 41706091·152.

Nearly every figure employed is set down, besides every figure exhibited is found direct, *per se*. No one could calculate the logarithm of any number, as 41706091·152, directly from the number itself, before I discovered the art and science of dual arithmetic.

I divide 41706091·152 by 4, and reduce it to 1·0426522788 with 1 commencing the number obtained. The reason why I divide by 4 is this; it is the square of the base (1 + 1) that is the square of 2; I place the square of 2 on the shaft of the arrow thus $\downarrow^{2}$.

The arrow points down in the ascending branch and up in the descending branch, because the larger number is below in the ascending branch; but the larger number is above in the descending branch.

If you observe, I begin with the fourth power of (1·01) = 1·04060401, as I observe at once that 1·04265228 number true to eight places of decimals begins with 104. But if I take 1·04060401, that is the fourth power of 1·1 or 14641, with an 0 between each figure. I take the fourth power of 101 as readily as I take the fourth power of 11. I have merely to place an 0 between each of the numbers given in the arithmetical triangle for 4.

$$\begin{array}{r} 104060401 \\ 104060 \\ \hline 104164461 \\ 104165 \\ \hline 104268626 \end{array} \quad \text{or} \quad \begin{array}{r|r|r|l} 104 & 060 & 401 & 1 \\ & 208 & 121 & 2 \\ & & 104 & 1 \\ \hline 104\,268\,626 & & & \end{array}$$

I observe, then, that 104164461 is too small, and I must increase it. But if I multiply it by the operative numbers 1, 2, 1, or add twice, I shall have too much, then the descending branch comes into operation.

From 104268626 obtained
Take 104265228 given

$$\begin{array}{rl} & 3398 \\ 10426) & 3128 \,(3259 \\ \cdots +) & \\ \hline & 270 \\ & 209 \\ & \hline & 61 \\ & 52 \\ & \hline & 9 \end{array}$$

The descending digits 3'2'2'9 are obtained by common division. or 3'2'5'9↑

Now, you observe that in reducing a dual number to a dual logarithm, I have to keep in mind only the four numbers, namely, 36052 and 34 for the descending branch, and 31018 and 33 for the ascending branch.

69314718 is the dual logarithm of 2 expressed thus ↓, (2). I add twice the logarithm of 2, written 2 ↓, (2), and seven times the logarithm of 10, written 7 ↓, (10). The powers of 10 and 2 are taken from the arrow $_{7}\!\uparrow^{2}$. Hence the dual logarithm of 41706091·152 is 1754615775; I multiply by 3 and divide by 7, then

$$1754615775 \times \tfrac{3}{7} = 3\downarrow,(10) \text{ and}$$
$$61202661, = \downarrow 6,4,0,3,6,4,2,1, = 1{\cdot}844165$$

Therefore, the 7th root of the cube of 41706091·152 is 1844·165.

I have only to count off eight figures from the right of 1754615775, then I have 17·54615775, the hyperbolic logarithm of 41706091·152.

The common logarithm of 41706091·152 is found by dividing 1754615775 by the dual logarithm of 10 operating by common division. I not only get the seventh root of the cube of the large number 41706091·152, but also the dual logarithm, the hyperbolic logarithm, and the common logarithm of 41706091·152. As a further illustration let us calculate the amount of £100 in 52 years, compound interest at 5 per cent. Nearly all the figures employed are set down:—

$$\begin{array}{rl} \downarrow 0,5, = 1{\cdot}0510 & 1005 \quad {}_{5}\!\downarrow 4, \\ & 4204 \\ \hline 105 & 105 \,|\, 209 \quad '1\uparrow_{5} \\ & 105 \,|\, 105 \\ \hline 105\,000 & 104 \quad '1\uparrow_{6} \\ & 105 \\ \hline 1{\cdot}05000000 & \end{array}$$

0'0'1'0'0'1'0'0↓0,5,0,0,4,000

4879015,
52

9758030
24395075

253708780, = ↓, (10) + ↓,2,4,4,0,8,3,0,3,

but ↓2,4,4,0,8,3,0,3, = 1·26427988.

∴ The amount £1264·27988 or £1264 5 7.

The rate of interest being 1·05, I find that the fifth power of 1·01 is

1·0510100501
1·05101005 to eight places of decimals.

I find that by one addition and two subtractions that 105101005 is reduced to 105. I reduce 0'0'1'0'0'1'0'0↓0,5,0,0,4,0,0,0, to a dual logarithm, by reducing the descending and ascending branch, taking the difference, and thus obtain the dual logarithm of 105 in a few seconds. I multiply the dual logarithm 4879015, by 52 by common multiplication, and obtain 253708780, the dual logarithm of the amount.

253708780,
230258509

23450271,

I subtract the logarithm of 10, and reduce 23450271, to a dual number ↓2,4,4,0,8,3,0,3, by the simple rule I have explained before. I then reduced this dual number to the amount, for

↓2,4,4,0,8,3,0,3, = 1·26427988
and (1·26427988) × (10) × (100) = 1264·27988

Without tables of interest or tables of logarithms it would be impossible, in any reasonable time, to obtain this result. The calculation would be as easy with 5½, 6, 6¼, or any other rate per cent. It is in the higher calculations of life annuities, the doctrine of chances, the business of the actuary respecting joint lives, that the great value of dual arithmetic will be found.

It may be said, "We have logarithms of our own; we do not want your logarithms; we have very good tables of logarithms, well calculated. Men have spent their lives in framing them, and laid out large sums in making calculating-machines, for the purpose of producing tables of logarithms." All very well; but I substitute for two systems of logarithms one system having all their properties, but none of their defects. Every logarithm in my table a school-boy can calculate, and

no logarithms that I know of but are made up by interpolation, the calculating machine only interpolates. It does not calculate as many people imagine.

The Rev. WALTER MITCHELL: I think the simplest way in which I can be of use to Mr. Byrne in explaining the more elementary parts of his new system is to suppose myself in Timbuctoo or some other out of the way place; that I am required to make calculations which can only be effected by means of logarithms; that I have no book of logarithms, or even a work on arithmetic or algebra; that I have forgotten the proof of the binomial theorem; that all I remember of algebra is the very simple proposition $a^m \times a^n = a^{m+n}$; m and n representing any whole number, positive or negative. Assuming only this elementary well-admitted principle of algebra, I shall proceed to show you every figure I should have to use to obtain the numbers by which Mr. Byrne can find the logarithm of any number, or conversely knowing the logarithm find the number corresponding to it.

Now, in doing this, I will make use of the simplest, but not the most expeditious methods. I will not assume even the law of binomial coefficients, I will use no process higher than simple multiplication or division. Even here I will limit myself. Being a bad calculator I will multiply by no number higher than ten, and I will record every figure of my work. I will also confine myself to one branch of Mr. Byrne's arithmetical art, the ascending branch, and show you that this alone will enable me to make any logarithmic calculations I may require.

To save time and figures, I make one more limitation. I will suppose that I am only required to use logarithms true to five places of figures. But the same processes I will show you can be readily and easily extended to 10, 20, or as many places of figures as may be required. Five places of figures will suit the object I have in view—the clear exposition of Mr. Byrne's elementary principles. Those conversant with arithmetical calculation well know the value of a table of logarithms true to five figures.

A dual number of the ascending branch is thus written:—

$$\downarrow u_1, u_2, u_3, u_4, u_5, u_6$$

where u_1, u_2, u_3, &c., represent figures, of any value from zero upwards, u_1, u_2, u_3, &c., are called the dual digits in the 1st, 2nd, 3rd, &c., positions, and the dual number itself is a contracted representation of a continued product.

Thus $\downarrow u_1, u_2, u_3, u_4, u_5, u_6$ is a contracted representation of the continued product—

$$\left(1 + \frac{1}{10}\right)^{u_1} \times \left(1 + \frac{1}{10^2}\right)^{u_2} \times \left(1 + \frac{1}{10^3}\right)^{u_3} \times \left(1 + \frac{1}{10^4}\right)^{u_4} \times$$

$$\left(1 \times \frac{1}{10^5}\right)^{u_5} \times \left(1 \times \frac{1}{10^6}\right)^{u_6}$$

just as in ordinary arithmetic, the number 1 2 3 4 5 6 is a contracted representation of the sum—

$$1 \times 10^5 + 2 \times 10^4 + 3 \times 10^3 + 4 \times 10^2 + 5 \times 10 + 6.$$

Now, though any number greater than unity may be represented by a dual number of the form $N = \downarrow u_1, u_2, u_3, u_4, u_5, u_6$, true to five places of figures, u_1 may sometimes be inconveniently large. We therefore reduce our number by dividing it by some power of 2 not greater than the cube, and by some power of 10, till it takes the form of a number whose first digit is unity, followed by a decimal point, and then one general expression for a dual number becomes—

$$N = 2^m 10^n \downarrow u_1, u_2, u_3, u_4, u_5, u_6,$$

where m is some number not greater than 3 and n does not exceed 7. But this modification renders the calculation of the dual numbers of 2 and 10 and their corresponding dual logarithms, necessary as bases for our system of calculation. By making n the power of 10 negative, we may convert any common number less than unity into a dual number.

The first thing, therefore, I have to do is to find the dual numbers and dual logarithms of the common numbers 2 and 10, and to do this by the aid of the simplest arithmetical process, without the assumption of any of the higher branches of algebra.

At our last meeting I showed how simply the values of the first nine digits of the dual system, in the first place, could be found by simple addition. Thus:—

$(1{\cdot}0)^0 = \downarrow 0, = 1{\cdot}0$
$\quad\quad\quad

I will now take a step beyond my elementary work at our last meeting. I then used nothing but addition in obtaining a dual number. That process may be much shortened by using multiplication. Thus :—

$$(1\cdot1)^5 \times (1\cdot1)^2 = (1\cdot1)^7 \text{ or } \downarrow 5, \times \downarrow 2, = \downarrow 5 + 2, = \downarrow 7$$

but $(1\cdot1)^5 = 1\cdot61051$
and $(1\cdot1)^2 = 1\cdot21 = 1 + \cdot2 + \cdot01$

$\therefore \downarrow 7 = 1\cdot61051 \times 1\cdot21$

$$\begin{aligned} \downarrow 5, &= 1\cdot61051 = A \\ &322102 = A \times \cdot2 \\ &16105 = A \times \cdot01 \end{aligned}$$

$\downarrow 7, = 1\cdot948717$ carried to 6 figures in order to be true for 5.

Hence $\downarrow 7$ can be obtained from the number representing $\downarrow 5$, or the number representing $\downarrow 5$ can be multiplied by $\downarrow 2$, by writing down the number and multiplying it, first by 2 and then by 1, putting down each of these results one figure further to the right than the number first written, and adding the three lines together. A process which gives the same result we arrived at before by two successive additions.

Again $(1\cdot1)^5 \times (1\cdot1)^3 = (1\cdot1)^8$ or $\downarrow 5 \times \downarrow 3 = \downarrow 5 + 3, = \downarrow 8$.

but $(1\cdot1)^3 = 1\cdot331 = 1 + \cdot3 + \cdot03 + \cdot001$.

$$\begin{aligned} (1\cdot1)^5 = 1\cdot61051 &= \downarrow 5 \\ \cdot483153 &= \downarrow 5 \times \cdot3 \\ 48315 &= \downarrow 5 \times \cdot03 \\ 1611 &= \downarrow 5 \times \cdot001 \\ (1\cdot1)^8 = 2\cdot143589 &= \downarrow 8, \end{aligned}$$

Hence a number may be multiplied by $\downarrow 3$, or $(1\cdot1)^3$, by writing down the number, under that line three times that number placing the figures one figure to the right, under that three times the number again placing the figures another figure back, and then the number itself placing the figures one step backwards, as shown above, and adding the result.

In a similar manner we may multiply a number by $(1\cdot1)^4$, or $\downarrow 4$, by writing down the number, then 4 times, 6 times, 4 times the number itself, putting each line one step to the right. Thus

$$\begin{aligned} (1\cdot1)^4 = 1\cdot4641 &= \downarrow 4 \\ 58564 &= \downarrow 4 \times \cdot4 \\ 87846 &= \downarrow 4 \times \cdot06 \\ 5856 &= \downarrow 4 \times \cdot004 \\ 146 &= \downarrow 4 \times \cdot0001 \\ (1\cdot1)^8 = 2\cdot143588 &= \downarrow 4 \times \downarrow 4 = \downarrow 8 \end{aligned}$$

To multiply a number by $(1\cdot1)^5$, the successive multipliers are 1, 5, 10, 10, 5, 1, putting each multiplication under the other, one figure back to the right for each line, and taking the turn, thus

$$\begin{array}{rrl}
(1\cdot1)^4 = 1\cdot4641 & = \downarrow 4 & \\
73205 & = \downarrow 4 \times \cdot05 & \\
146410 & = \downarrow 4 \times \cdot10 & \\
14641 & = \downarrow 4 \times \cdot0010 & \\
732 & = \downarrow 4 \times \cdot0005 & \\
15 & = \downarrow 4 \times \cdot00001 & \\
\hline
(1\cdot1)^4 \times (1\cdot1)^5 \quad 2\cdot357948 & = \downarrow 4, \times \downarrow 5, = \downarrow 9, &
\end{array}$$

Having established the rule for multiplying numbers by the first five dual digits in the first position, we may now proceed to dual digits in the second position.

$$\begin{array}{lll}
(1\cdot01)^0 \quad \downarrow 0,0, & 1\cdot0 \mid 10 & \\
\hline
(1\cdot01)^1 \quad \downarrow 0,1, & 1\cdot0 \mid 10 \mid 10 & 1 + \cdot01 \\
\hline
(1\cdot01)^2 \quad \downarrow 0,2, & 1\cdot0 \mid 20 \mid 10 \mid 10 & 1 + \cdot02 + \cdot0001 \\
\hline
(1\cdot02)^3 \quad \downarrow 0,3, & 1\cdot0 \mid 30 \mid 30 \mid 1 \mid 10 & 1 + \cdot03 + \cdot0003 + \cdot000001 \\
\hline
(1\cdot01)^4 \quad \downarrow 0,4, & 1\cdot0 \mid 40 \mid 60 \mid 4 \mid 10 & 1 + \cdot04 + \cdot0006 + \cdot000004 \\
\hline
(1\cdot00)^5 \quad \downarrow 0,5, & 1\cdot051010 & 1 + \cdot05 + \cdot0010 + \cdot000010
\end{array}$$

Whence, as before, we may deduce these rules, to multiply a number

by $\downarrow 0, 2$, we multiply it by 1, 2, and 1
by $\downarrow 0, 3$, „ 1, 3, 3, and 1
by $\downarrow 0, 4$, „ 1, 4, 6, and 4
by $\downarrow 0, 5$, „ 1, 5, 10, and 10

putting each succeeding line two figures to the right, and then taking the sum of the whole.

Again :—

$$\begin{array}{llll}
\downarrow 0,0,0 & 1\cdot00 \mid 100 & \downarrow 0,0,0,0 & 1\cdot000 \mid 100 \\
\hline
\downarrow 0,0,1 & 1\cdot00 \mid 100 \mid 100 \mid 1 & \downarrow 0,0,0,1 & 1\cdot000 \mid 100 \mid 100 \\
\hline
\downarrow 0,0,2 & 1\cdot00 \mid 200 \mid 100 \mid 1 \mid 2 & \downarrow 0,0,0,2 & 1\cdot000 \mid 200 \mid 100 \\
\hline
\downarrow 0,0,3 & 1\cdot00 \mid 300 \mid 100 \mid 3 & \downarrow 0,0,0,3 & 1\cdot000 \mid 300 \mid 100 \\
\hline
\downarrow 0,0,4 & 1\cdot00 \mid 400 \mid 100 \mid 6 \mid 4 & \downarrow 0,0,0,4 & 1\cdot000 \mid 400 \mid 100 \\
\hline
\downarrow 0,0,5 & 1\cdot005010 & \downarrow 0,0,0,5 & 1\cdot000500
\end{array}$$

$$\begin{array}{ll}
\downarrow 0,0,0,0,0 & 1\cdot0000 \mid 10 \\
\hline
\downarrow 0,0,0,0,1 & 1\cdot0000 \mid 10 \mid 10 \\
\hline
\downarrow 0,0,0,0,2 & 1\cdot0000 \mid 20 \mid 10 \\
\hline
\downarrow 0,0,0,0,3 & 1\cdot0000 \mid 30 \mid 10 \\
\hline
\downarrow 0,0,0,0,4 & 1\cdot0000 \mid 40 \mid 10 \\
\hline
\downarrow 0,0,0,0,5 & 1\cdot000050
\end{array}$$

Now, inspecting the above tables, we see that we can get this general rule for multiplying any number by a dual number in any position, by multiplying the number by 1 and 1 if the dual digit be 1; by 1, 2, and 1, if the dual digit be 2; by 1, 3, 3, and 1 if the dual digit be 3; 1, 4, 6, 4, 1 if the digit be 4; and by 1, 5, 10, 10, 5, and 1 if the digit be 5, putting each line of these multiplications as many figures to the right as the numerical value of the position of the dual digit, and then taking the sum of these numbers. For example, to find the numerical value of the dual number ⌊7, 2, 6, 0, 7, 8.

$$
\begin{aligned}
\lfloor 4, = \quad & 1{\cdot}4641 && = A \\
& 43923 && = A \times \frac{3}{10} \\
& 43923 && = A \times \frac{3}{10^2} \\
& 1464 && = A \times \frac{3}{10^3} \\
\lfloor 4, \times \lfloor 3, = \lfloor 7, = \quad & \overline{1{\cdot}9|48|71|7} && = D \\
& \quad 38|97|4 && = B \times \frac{2}{10^2} \\
& \quad\quad 19|5 && = B \times \frac{1}{10^4} \\
\lfloor 7,2, = \quad & \overline{1{\cdot}98|78|86} && = C \\
& \quad\quad 99|39 && = C \times \frac{5}{10^3} \\
& \quad\quad\quad 2|0 && = C \times \frac{10}{10^6} \\
\lfloor 7,2,5, = \quad & \overline{1{\cdot}99|78|45} && = D \\
& \quad\quad\quad 199|8 && = D \times \frac{1}{10^3} \\
\lfloor 7,2,6, = \quad & \overline{1{\cdot}9998|43} && = E \\
& \quad\quad\quad 1|40 && = E \times \frac{7}{10^5} \\
\lfloor 7,2,6.0,7, = \quad & \overline{1{\cdot}99998|3} && = F \\
& \quad\quad\quad\quad 1|6 && = F \times \frac{8}{10^6} \\
\lfloor 7,2,6,0,7,8, = \quad & \overline{1{\cdot}999999}
\end{aligned}
$$

Hence ⌊7, 2, 6, 0, 7, 8 = 2 true to five places of figures.

Now to give an example of the inverse process, or given the common number 1·25 to find its dual representative.

$$
\begin{array}{l|l|l|l}
1{\cdot}2 & 1\,0 & = \downarrow 2 & \\
 & 3\,6 & & \\
 & 3\,6 & 3 & \\
 & & 1 & \\
\hline
1{\cdot}2\,4 & 6\,6\,6 & 4 & = \downarrow 2,3 \\
 & 2\,4\,9 & 3 & \\
 & & 1 & \\
\hline
1{\cdot}2\,4\,9 & 1\,5\,8 & & = \downarrow 2,3,2 \\
 & 7\,5\,0 & & \\
\hline
1{\cdot}2\,4\,9\,9 & 0\,8 & & = \downarrow 2,3,2,6 \\
 & 8\,8 & & \\
\hline
1{\cdot}2\,4\,9\,9\,9\,6 & & & = \downarrow 2,3,2,6,7 \\
 & 4 & & \\
\hline
1{\cdot}2\,5\,0\,0\,0\,0 & & & = \downarrow 2,3,2,6,7,3
\end{array}
$$

$$
\begin{array}{l|l}
1{\cdot}2 & 50 \\
1{\cdot}2 & 10 \\
\hline
1{\cdot}2) & 40(3
\end{array}
$$

$$
\begin{array}{l|l}
1{\cdot}25 & \\
1{\cdot}24 & 666 \\
\hline
124) & 334(2
\end{array}
$$

$$
\begin{array}{l|l}
1{\cdot}250 & \\
1{\cdot}249 & 158 \\
\hline
1249) & 842(673 \\
 & 750 \\
 & \overline{92} \\
 & 88 \\
 & \overline{4} \\
 & 4 \\
 & \overline{\cdots}
\end{array}
$$

To explain the above example, since $\downarrow 2 = 1{\cdot}21$ and $\downarrow 3 = 1{\cdot}331$, we know that the first dual digit of the number representing $1{\cdot}25$ must be 2.

To find the second digit we write down the number 1·250, and we subtract from it the first four figures of $\downarrow 2$ and we get 40. This we divide by the first two figures of $\downarrow 2$, or 1·21, and we obtain 3, which is the second digit, we then find the value of $\downarrow 2, 3$.

We then subtract the first six figures of $\downarrow 2, 3$, from 1·25, and get the remainder 334; this divided by the first three figures of $\downarrow 2, 3$ gives 2, the third dual digit.

We then multiply $\downarrow 2, 3$ by $\downarrow 0, 0, 2$, and obtain $\downarrow 2, 3, 2$, we subtract the first seven figures of this from 1·25, and obtain the number 842, this divided by 1249, the first four figures of $\downarrow 2, 3, 2$, according to the rule of contracted division in decimals, gives at once the next three dual digits, which are 6, 7, and 3, and we find that $1{\cdot}25 = \downarrow 2, 3, 2, 6, 7, 3$ true to five places of figures.

$$\text{Now } \frac{10}{8} = 1{\cdot}25 = \downarrow 2,3,2,6,7,3$$

$$\therefore 10 = 2^3 \downarrow 2,3,2,6,7,3.$$

Hence we have found the dual numbers representing the numbers 2 and 10; which are essential for our future operations.

We now proceed to the calculation of a dual logarithm. As a first step towards this we will show that $\downarrow 1 = \downarrow 0, 9, 5, 7, 6, 0$.

$$\text{For } \downarrow 0,5 = 1{\cdot}0\,|\,5\,1\,|\,0\,1\,|\,0 = A$$
$$4\,2\,|\,0\,4\,|\,0 = A \times \frac{4}{10^2}$$
$$6\,3\,|\,1 = A \times \frac{6}{10^4}$$
$$4 = A \times \frac{4}{10^6}$$

$$\downarrow 0,9, = 1{\cdot}0\,9\,|\,3\,6\,8\,|\,5 = B$$
$$5\,4\,6\,|\,8 = B \times \frac{5}{10^3}$$
$$1\,|\,1 = B \times \frac{10}{10^6}$$

$$\downarrow 0,9,5, = 1{\cdot}0\,9\,9\,|\,1\,6\,4 = C$$
$$5\,5\,0 = C \times \frac{5}{10^4}$$

$$\downarrow 0,9,5,5, = 1{\cdot}0\,9\,9\,|\,7\,1\,4 = D$$
$$2\,2\,0 = D \times \frac{2}{10^4}$$

$$\downarrow 0,9,5,7, = 1{\cdot}0\,9\,9\,9\,|\,3\,4 = E$$
$$5\,5 = E \times \frac{5}{10^5}$$

$$\downarrow 0,9,5,7,5 = 1{\cdot}0\,9\,9\,9\,|\,8\,9 = F$$
$$1\,1 = F \times \frac{1}{10^2}$$

$$\downarrow 0,9,5,7,6,0 = 1{\cdot}1\,0\,0\,0\,0\,0 = \downarrow 1$$

A result which shows that two dual numbers, having different digits, may represent the same common number.

Again

$$\downarrow 0,0,5 = 1{\cdot}0\,0\,|\,5\,0\,1\,|\,0$$
$$4\,0\,2\,|\,0$$
$$6$$

$$\downarrow 0,0,9 = 1{\cdot}0\,0\,9\,|\,0\,3\,6$$
$$5\,0\,5$$

$$\downarrow 0,0,9,5 = 1{\cdot}0\,0\,9\,|\,5\,4\,1$$
$$4\,0\,4$$

$$\downarrow 0,0,9,9 = 1{\cdot}0\,0\,9\,9\,|\,4\,5$$
$$5\,0$$

$$\downarrow 0,0,9,9,5 = 1{\cdot}0\,0\,9\,9\,9\,|\,5$$
$$5$$

$$\downarrow 0,0,9,9,5,5 = 1{\cdot}0\,1\,0\,0\,0\,0 = \downarrow 0,1.$$

To take another example—

$$\begin{aligned}
\downarrow 0,0,0,5 &= 1{\cdot}000\,|500\\
&\qquad\quad\ \ |500\\
&\qquad\quad\ \ \overline{\qquad\qquad}\\
\downarrow 0,0,0,10 &= 1{\cdot}001\,000 = \downarrow 0,0,1\\
\downarrow 0,0,0,0,5 &= 1{\cdot}0000\,|50\\
&\qquad\quad\ \ |50\\
&\qquad\quad\ \ \overline{\qquad\qquad}\\
\downarrow 0,0,0,0,10 &= 1{\cdot}0001\,00 = \downarrow 0,0,0,1\\
\downarrow 0,0,0,0,0,5 &= 1{\cdot}00000\,|5\\
&\qquad\quad\ \ |5\\
&\qquad\quad\ \ \overline{\qquad\qquad}\\
\downarrow 0,0,0,0,0,10 &= 1{\cdot}00000\,0 = \downarrow 0,0,0,0,1
\end{aligned}$$

Now, tabulating these results, we have these important formulæ—

$$\begin{aligned}
\downarrow 1, &= 0,9,5,7,6,0\\
\downarrow 0,1, &= 0,0,9,9,5,5\\
\downarrow 0,0,1, &= 0,0,0,10,0,0\\
\downarrow 0,0,0,1, &= 0,0,0,0,10,0\\
\downarrow 0,0,0,0,1, &= 0,0,0,0,0,10
\end{aligned}$$

Now reverting to our original definition of a dual number,

$$\mathrm{N} = \left(1+\frac{1}{10}\right)^{u_1}\left(1+\frac{1}{10^2}\right)^{u_2}\left(1+\frac{1}{10^3}\right)^{u_3}\ \&\mathrm{c.} = \downarrow u_1,u_2,u_3,\ \&\mathrm{c.}$$

$$\text{Let } \mathrm{M} = \left(1+\frac{1}{10}\right)^{w_1}\left(1+\frac{1}{10^2}\right)^{w_2}\left(1+\frac{1}{10^3}\right)^{w_3}\ \&\mathrm{c.} = \downarrow w_1,w_2,w_3,\ \&\mathrm{c.}$$

and taking for granted the algebrical principle, that $a^{\mathrm{m}} \times a^{\mathrm{n}} = a^{\mathrm{m}+\mathrm{n}}$

$$\mathrm{N} \times \mathrm{M} = \left(1+\frac{1}{10}\right)^{u_1+w_1}\left(1+\frac{1}{10^2}\right)^{w_2+w_2}\left(1+\frac{1}{10^3}\right)^{w_3+w_3}\ \&\mathrm{c.}$$

$$= \downarrow (u_1+w_1)\,(u_2+w_2)\,(u_3+w_3),\ \&\mathrm{c.}$$

or, in other words, to multiply two dual numbers together, we add their digits.

$$\begin{aligned}
\text{Hence since } \downarrow 0,0,0,0,1 &= \downarrow 0,0,0,0,0,10\\
\text{and } \downarrow 0,0,0,0,1 &= \downarrow 0,0,0,0,0,10\\
\therefore\ \downarrow 0,0,0,0,2 &= \downarrow 0,0,0,0,0,20\\
\text{but } \downarrow 0,0,0,0,1 &= \downarrow 0,0,0,0,0,10\\
\therefore\ \downarrow 0,0,0,0,3 &= \downarrow 0,0,0,0,0,30\\
\text{Similarly } \downarrow 0,0,0,0,4 &= \downarrow 0,0,0,0,0,40
\end{aligned}$$

and so on, so that generally $= \downarrow 0,0,0,0,n = \downarrow 0,0,0,0,0,n \times 10$

$$\text{hence } \downarrow 0,0,0,0,10 = \downarrow 0,0,0,0,0,100$$
$$\text{but } \downarrow 0,0,0,1 = \downarrow 0,0,0,0,10$$
$$\therefore \downarrow 0,0,0,1 = \downarrow 0,0,0,0,0,100$$

Similarly it may be shown that—

$$\downarrow 0,0,1 = \downarrow 0,0,0,0,0,1000$$
$$\downarrow 0,0,2 = \downarrow 0,0,0,0,0,2000$$
$$\text{&c.} \qquad \text{&c.}$$

$$\text{but } \downarrow 0,1 = \downarrow 0,0,9,9,5,5$$
$$= \downarrow 0,0,9 \times \downarrow 0,0,0,9 \times \downarrow 0,0,0,0,5 \times \downarrow 0,0,0,0,5$$
$$= \downarrow 0,0,0,0,0,9000$$
$$\times \downarrow 0,0,0,0,0, \ 900$$
$$\times \downarrow 0,0,0,0,0, \ \ 50$$
$$\times \downarrow 0,0,0,0,0, \ \ \ 5$$
$$= \downarrow 0,0,0,0,0,9955$$

$$\therefore \downarrow 0,9 = \downarrow 0,0,0,0,0,89595 \quad \text{since } 9 \times 9955 = 89595$$

$$\text{Again } \downarrow 1, = \downarrow 0,9,5,7,6,0$$
$$= \downarrow 0,9,0,0,0,0$$
$$\times \downarrow 0,0,0,0,0,5760$$
$$= \downarrow 0,9 \times \downarrow 0,0,0,0,0,5760$$
$$= \downarrow 0,0,0,0,0,89595$$
$$\times \downarrow 0,0,0,0,0, \ 5760$$
$$= \downarrow 0,0,0,0,0,95355$$

Hence, tabulating these results, we have

$$\downarrow 1, = 0,0,0,0,0,95355$$
$$\downarrow 0,1, = 0,0,0,0,0, \ 9955$$
$$\downarrow 0,0,1, = 0,0,0,0,0, \ 1000$$
$$\downarrow 0,0,0,1, = 0,0,0,0,0, \ \ 100$$
$$\downarrow 0,0,0,0,1, = 0,0,0,0,0, \ \ \ 10$$
$$\downarrow 0,0,0,0,0,1, = 0,0,0,0,0, \ \ \ \ 1 \ .$$

or going back to our original notation, we find

$$1{\cdot}1 = \downarrow 1, = \left(1 + \frac{1}{10^6}\right)^{95355}$$

$$1{\cdot}01 = \downarrow 0,1, = \left(1 + \frac{1}{10^6}\right)^{9955}$$

$$1{\cdot}001 = \downarrow 0,0,1 = \left(1 + \frac{1}{10^6}\right)^{1000}$$

In other words, according to the general definition of a logarithm, that if $N = B^L$, or a number N, is equal to another number B raised to the

power of L, L is the logarithm of the number N to the base B. The whole numbers 1, 10, 100, 1000, 9955, and 95355 are the logarithms of 1·000001, 1·00001, 1·0001, 1·001, 1·01, and 1·1 all to the same base $(1 + \frac{1}{10^6})$.

Such logarithms as these Mr. Byrne calls dual logarithms. I would rather call them Byrne's logarithms, so to associate them with their inventor, as we have the logarithms of Briggs and Napier with that of their discoverers.

Having now obtained the dual logarithms of ⌊1, ⌊0, 1, ⌊0, 0, 1, &c., we can now find the dual logarithms of 2 and 10.

We have seen that 2 = ⌊7, 2,6, 0, 7, 8,

$$\begin{aligned} \text{But } \lfloor 7 &= \lfloor 0,0,0,0,0,7 \times 95355 \\ \lfloor 0,2 &= \lfloor 0,0,0,0,0,2 \times \ 9955 \\ \lfloor 0,0,6,0,7,8 &= \lfloor 0,0,0.0,0, \qquad 6078 \end{aligned}$$

$$\begin{aligned} \therefore 2 &= \lfloor 0,0,0,0,0,667485 \\ &\times \lfloor 0,0,0,0,0, \ 19910 \\ &\times \lfloor 0,0,0,0,0, \ \ 6078 \\ &= \lfloor 0,0,0,0,0,693473 \\ &= \left(1 + \frac{1}{10^6}\right)^{693473} \end{aligned}$$

$$\begin{aligned} \text{Again } 10 &= 2^3 \times 1{\cdot}25 \\ &= 2^3 \times \lfloor 2,3,2,6,7,3. \end{aligned}$$

$$\begin{aligned} \text{Now } 2 \times 95355 &= 190710 \\ 3 \times \ 9955 &= \ 29865 \\ &\quad\ \ 2673 \\ &\quad\overline{223248} \end{aligned}$$

$$\therefore \lfloor 2,3,2,6,7,3 = \lfloor 0,0,0,0,0,223248$$

$$\text{but } 2 = \left(1 + \frac{1}{10^6}\right)^{693473} = 0,0,0,0,0,693473$$

$$\therefore \ 2^3 = \left(1 + \frac{1}{10^6}\right)^{2080419} = \lfloor 0,0,0,0,0,2080419$$

$$\begin{aligned} \text{Hence } 10 &= \lfloor 0,0,0,0,0, \ 223248 \\ &\times \lfloor 0,0,0,0,0,2080419 \\ &= \lfloor 0,0,0,0,0.2303667 \\ &= \left(1 + \frac{1}{10^6}\right)^{2303667} \end{aligned}$$

I have thus by a rigid demonstration, using no recondite algebraical artifices, using only the commonest arithmetical processes, found the dual logarithms, of ⌊ 1 , ⌊ 0 , 1 , ⌊ 0, 0, 1, &c., as well as those of 2 and 10, which are all the data I require to enable me to perform any

logarithmic computation to 5 figures, without the aid of any table whatever.

Now just to take one case as an example, suppose I want to find the 7th root of the 5th power of 3·141593

$$2|3\cdot141593$$
$$1\cdot570797$$

Now first I find the dual number corresponding to 1·570796 by the method I have already shown you, all the working, every figure stands thus:

$$\begin{array}{r} 1\cdot4|64|10|0 = \downarrow 4 \\ |73|20|5 \times 5 \\ |46|4 \times 10 \\ 1|5 \times \downarrow 10 \\ \hline 1\cdot5|38|78|4 = \downarrow 4,5 \\ |30|77|6 \\ 15|4 \\ \hline 1\cdot5\ 69\ 71\ 4 = \downarrow 4,7,0 \end{array}$$

$$\begin{array}{r} 15|70 \\ 14|64 \\ \hline 14)106(7 \text{ second digit} \\ \\ 157|079 \\ 156|971 \\ \hline 156)108(0 \text{ third dual digit} \end{array}$$

$$\begin{array}{r} 1570|797 \\ 1569|714 \\ \hline 1570)1083(690 \text{ next three digits} \\ \dot{9}42 \\ \hline 141 \\ 141 \\ \hline \cdots \end{array}$$

Hence $3\cdot141593 = 2|\downarrow 4,7,0,6,9,0$

We have next to turn this into a dual logarithm:

$$\begin{array}{rrl} 4 \times 95355 = & 381420 & = 4 \times \text{dual log. } 1\cdot1 \\ 7 \times \ 9955 = & 69685 & = 7 \times \text{dual log. of } 1\cdot01 \\ & 690 & \\ \hline & 451795 & = \text{dual log. of } \downarrow 4,7,0,6,9,0 \\ & 693473 & = \text{dual log. of } \dot{2} \\ \hline & 1145268 & = \text{dual log. of } 3\cdot141593 \\ & 5 & \\ \hline & 7|5726340 & \\ & 818049 & = \text{dual log. of } (3\cdot141593)^{\frac{5}{7}} \end{array}$$

I have now got the dual logarithm of the 5th power of the 7th root of

π, the ratio of the circumference of a circle to its diameter. Now I must find the dual number corresponding to this logarithm :

818049
693473 = dual log. of 2

95355)124576(1
95355

9955)29221(2
19910

9311

and I say from this that 2|1,2,9,3,1,1 is a dual number, whose dual logarithm is 818049, and I obtain it thus: I subtract from 818049, which is greater than the dual logarithm of 2, the dual logarithm of 2, and I get the remainder 124576.

I see how often this contains 95355 the dual logarithm of 1·1, and I find it contained once with a remainder 29221.

I see how often this remainder contains 9955, the dual logarithm of 1·01, and I find it twice with a remainder 9311.

And if I convert 2|1,2,9,3,1,1 into a dual logarithm, I shall find that I have only exactly reversed the process I have just used for turning a dual logarithm into a dual number. But to proceed—

1.1| = |1,
22|00
11

1·12|211 = |1,2,
561|1
1|1

1·12|773|2 = |1,2,5,
451|1
1|7

1·132|250 = |1,2,9,
340

1·1325|90 = |1,2,9,3
11

1·13260|1 = |1,2,9,3.1
1

1·132602 = |1,2,9,3,1,1
2

2·265204 = 2|1,2,9,3,1,1

And I affirm that $(3{\cdot}141593)^{\frac{5}{7}} = 2{\cdot}26520$ true to the last figure.

Now, I have given you a strict demonstration of a problem that almost any mathematician would have asserted to be impossible before

Mr. Byrne published his dual arithmetic. I think I may defy any one to show me any practical method ever published before that work, which would have enabled you to find a logarithm of such a number as 3·141593. Nor am I aware of the slightest hint after finding the logarithm of a number to any base, which would enable you to calculate the number corresponding to that base. Yet I think I have made good my position that as a pupil of Mr. Byrne's, I could solve any problem requiring logarithms, though I were at Timbuctoo and without the aid of any tables or any mathematical work.

Now I go a step further and tell you, that though I have only used a table of logarithms to 5 figures, I have got as accurate a result as if I had used a table of logarithms to 7 places of figures. For if I had used such a table, I should have had the following work:—

$$\log. 3{\cdot}1415926 = 0{\cdot}4971499$$
$$5$$
$$7\,|\,2{\cdot}4857495$$
$$\cdot 3551071$$

Again from the tables I find

$$\log. 2{\cdot}2652 = {\cdot}3551066.$$

And using the table of proportional parts, I further find that

$$\log. 2{\cdot}265203 = {\cdot}351071$$

Now as it is well known that I cannot rely on my last figure, I find that by using the dual method to six figures, I have arrived at the same result as if I had used a table of seven figure logarithms of Briggs, or logarithms to the base 10. Some of my Cambridge friends to whom I have spoken of this method, meet me with this objection: This is all very well if we had no tables, but we have tables, and they suit our purposes very well. Now most Cambridge men have little to do with figures, if they had they would soon learn we have no tables so accurate as to be relied on; but suppose they were, is it of no value for a mathematician to be able, if necessary, and if placed under circumstances of difficulty, to be enabled to dispense with them. Why do our arithmetics still retain the rules for square root and cube root? Is it not from a feeling that the day may come when the arithmetical computist may have to find the square root or cube root of a number without having tables of logarithms to enable him to dispense with those most difficult arithmetical rules. In all the processes I have brought before you to-night have I shown you one at all equal in difficulty to the extraction of the cube root? But Mr. Byrne's dual arithmetic enables me to calculate any algebraical formulæ, however complicated, without adapting those formulæ to logarithmic computation by the use of subsidiary angles and other devices. Nay more, in the Analysis of Dual Arithmetic which I now hold in my hand, Mr. Byrne has solved questions by methods as simple as any I have

shown you, problems where the Theorems of Lagrange and Laplace fail to give a solution. In a work now passing through the press, Mr. Byrne gives a direct solution to such a question as this without tables. An annuity of £140 left unpaid for 33 years amounted to £16650·71552 at compound interest, find the rate per cent.?

The solution of this question leads to an equation of 33 dimensions, in which the unknown quantity not only appears in the 33rd, but also in the 1st power. The equation also has the number 1 for a root, but 1 is not the answer. Now, such an equation as this is hardly soluble by any known process when it has a root like this very near 1. Mr. Byrne's method gives this root by a single direct unerring process. Mr. Byrne seeks to carry his methods into the highest branches of mathematics; he has shown you some startling problems. But if he had done nothing more than invent such methods of calculation as I have shown you to-night, I think I may appeal to Professor Young to bear me out in saying that it is one of the most marvellous improvements that ever has been made in the history of mathematical science.

Professor YOUNG: Yes certainly.

Mr. MITCHELL: I am sure that few men in England know so much of the higher branches of algebra and the numerical solution of high equations as Professor Young. In conclusion I may remark that as Mr. Byrne developes his methods of calculation he always takes care that every direct process he used, can be as readily reversed. I have good grounds, therefore, to hope from what he has done that his calculus of form will enable us to do what the integral calculus, the calculus of differences, and the calculus of functions, have failed to accomplish. I wish to take an opportunity of correcting a misapprehension on the part of some, the analysis of the dual arithmetic bears my name because I arranged the elementary part of it, but I wish distinctly to state that all the important rules and especially the solution of questions in the higher branches of mathematics, were all communicated to me by Mr. Byrne.

The CHAIRMAN: I want to ask one question about the explanation of what you are alluding to. Is it a work published or unpublished, or is it anything that has come before the meeting?

Mr. MITCHELL: I am alluding to the first books.

The CHAIRMAN: It is only to clear it up, if you will mention the title.

Mr. MITCHELL: It is the Analysis.

The CHAIRMAN: Because most of us have never seen one of the books.

Mr. MITCHELL: I mean to say as an earnest of what Mr. Byrne can do, he has shown in the Analysis of the Dual Arithmetic which is published the power of that art in solving equations, even where the differential calculus in its higher branches has entirely failed. I have endeavoured to put before you as simply as I can, the new method of arithmetical calculation Mr. Byrne has introduced. In doing so, perhaps I have been unnecessarily prolix. But I wished to sacrifice rapidity of calculation to clearness, in bringing before you methods of great novelty.

Professor YOUNG: I come here quite as a novice. I have not had the opportunity of reading any of Professor Byrne's writings on this subject, although I am quite familiar with his name. However, I have seen enough, and have taken in enough to be convinced that there really is a great deal more in arithmetic than I had previously imagined; and I think Mr. Byrne has brought out some particulars that have been very clearly illustrated by himself and by Mr. Mitchell that cannot fail to be of very remarkable application in almost every part of practical mathematics. I think Mr. Mitchell has alluded to its utility in developing some of the higher theorems of analysis. I do not understand perhaps whether you consider it will facilitate the analytical investigation or the numerical calculation.

Mr. MITCHELL: Numerical calculation.

Professor YOUNG: That is what we want, and that, in fact, is a very practical problem. We do not want the symbols, but the arithmetical values, and I think Mr. Byrne has enunciated a mode of proceeding that certainly will put into the shade everything hitherto put forward, in the shape of a numerical work.

Mr. BYRNE: I feel very much obliged to Mr. Mitchell for the candid way in which he has spoken, and also to Professor Young. I have also discovered a new mathematical science, called the Calculus of Form, mentioned in my works already published. There is no expression in the differential or integral calculus that I cannot differentiate or integrate. Some examples I have given to Mr. Scott Russell, when writing his great work on Naval Architecture, lately published.

The CHAIRMAN: I suppose it remains with me to close this meeting. I regret very much Captain Fishbourne is not here—he is unable to attend—because I believe he is almost the only member of our Institution, or certainly of the Council, who has given any attention whatever to this subject. It is evidently a subject of very large dimensions; it is evidently one which requires a great deal of study, and it would really be presumptuous in any man who has not studied it very carefully to say anything on the subject here. As far as I am personally concerned I really do not attempt to know anything whatever about it. I never saw a figure connected with it until our last meeting. I think there is another difficulty we labour under here to-night, it is that in Mr. Mitchell's illustrations he was alluding to works which, so far as I understand, are scarcely published yet. He was rather sketching out what Mr. Byrne will do and is prepared to do, and may be able to accomplish when these works are published. It would be manifestly impossible even for the best mathematician to pass an opinion upon works which are as yet in embryo. I have a letter in my pocket from a mathematician of the very highest order, who had read a small work of Mr. Byrne's, I think he cal's it a 14s. work; it is evidently very elementary, and therefore I shall not read that letter. It was my intention to read it; but I think it really would not be right after what has fallen from Mr. Mitchell, to put forth the opinions of a very high mathematician, who has evidently only looked at the very beginning of Mr. Byrne's subject, and is not aware, so far as I understand from his note to me, of those works in the higher branches which are about to be placed

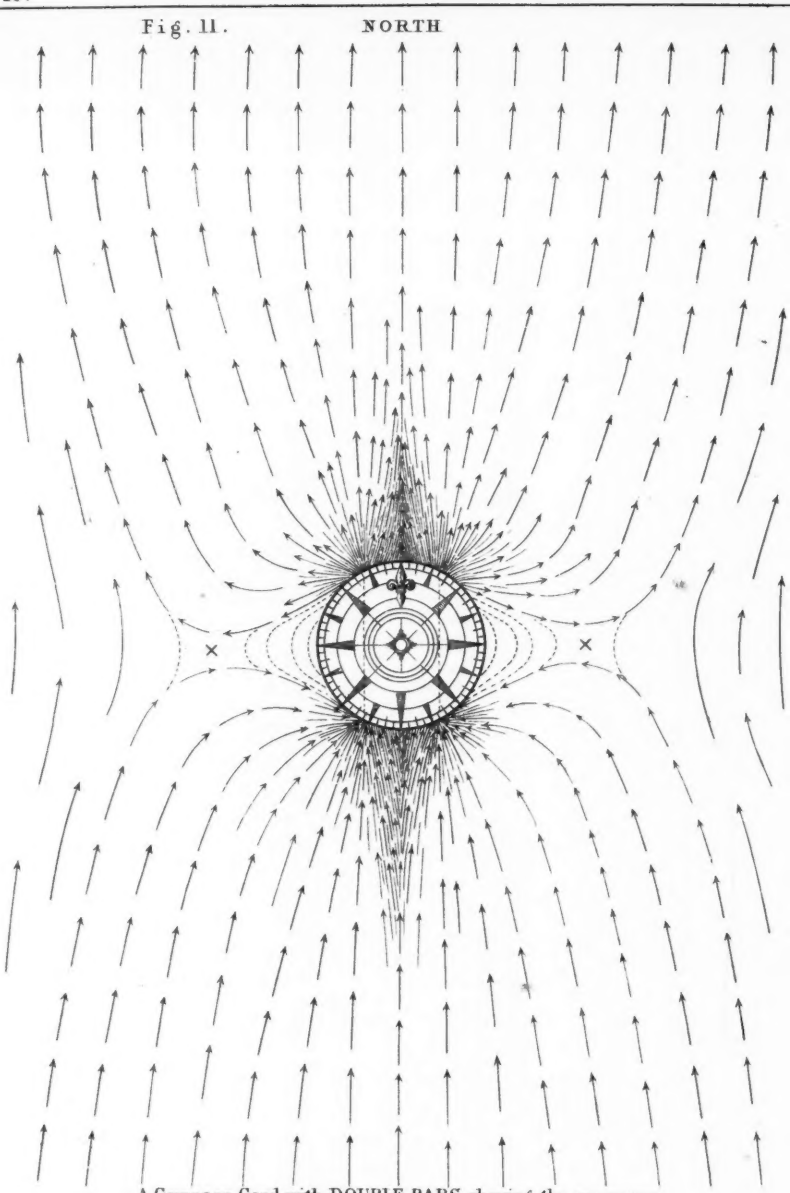
before the public. I shall therefore not read the letter of that eminent mathematician.

Mr. REDDIE: I would suggest that you should read the letter without mentioning the name; because if there are any deficiencies in the work which he has examined, they might be supplied. Mr. Mitchell is engaged by Messrs. Bell and Daldy to criticise Mr. Byrne's works; and the book Mr. Mitchell was alluding to is a work published at 14s., about a year ago; the analysis of it at the beginning being written by himself.

The CHAIRMAN: Of course it is difficult to explain what is not before the meeting; but I will say one thing that my correspondent does mention in the letter; he says there is a great deal in the system, and that Mr. Byrne has displayed a vast deal of ingenuity in carrying it out. The letter does not give any opinion that would carry any weight with regard to any part of the higher branches of mathematics. I am only mentioning it to show we are all anxious, as far as we can, to gather opinions from those who are able to give them on this subject. It is, as I said before, a subject upon which hardly any member of either of the services, who compose the greater part of the members of this Institution, are able to give an opinion—certainly not in the present stage of the subject. I am sure we must all hope Mr. Byrne will prosecute his labours, and that he will, in time, reduce and simplify these certainly very difficult branches of mathematics that some of us have just looked at with dread, for nothing can look so frightfully complicated as some of these hard analyses, and if he is going to enable us to put them to practical use, which is, after all, the great object, I am sure everybody will be highly indebted to him.

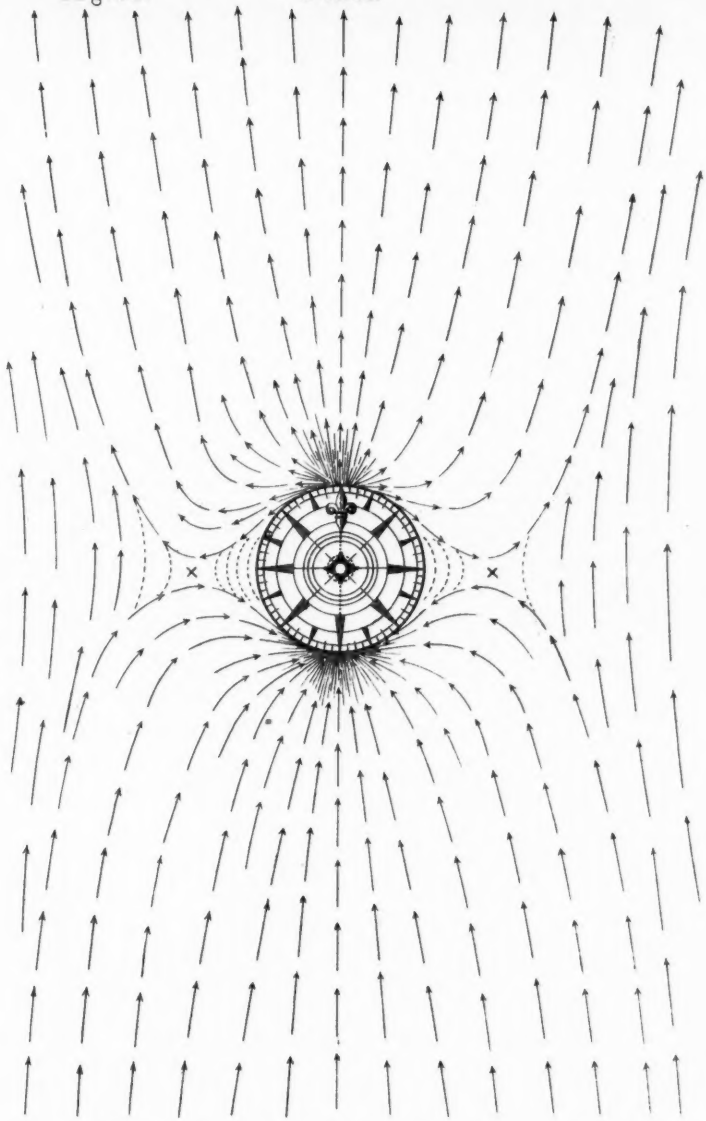
It only remains for me to express the thanks of the meeting to Mr. Byrne in the first place, who has brought the subject before us, who is, in fact, the inventor of it. And I think I must also include Mr. Mitchell for the manner in which he has explained, I must say very clearly indeed, so far as one can follow him, the very abstruse, for it is abstruse to us who know nothing about it, subject which has been brought before us. I am sure Mr. Mitchell's explanations show, if he is only a pupil, he has been a very diligent one, and he brings to bear upon the whole subject a clearness of mind which proves how long he must have been engaged in mathematical studies.

Fig. 11.



A Compass Card with DOUBLE BARS shewing the appearance of the Magnetic Brushes about $\frac{1}{6}^{th}$ the size.
× × Neutral spaces.

Fig. 12.



A Compass Card with a SINGLE BAR shewing the appearance of the "Magnetic Brushes" at both ends, about $^{1}/_{6}$th the size.
x x Neutral spaces.

J. Jobbins

Fig. 7.

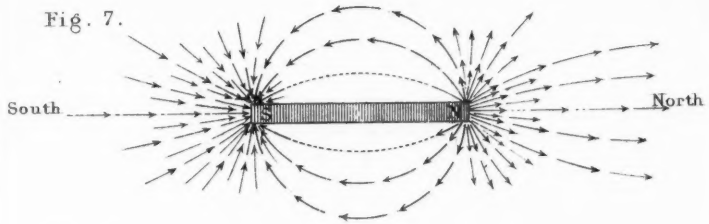


Fig. 8.

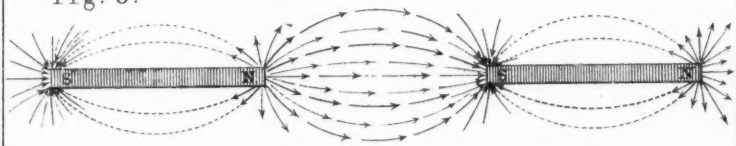


Fig. 9.

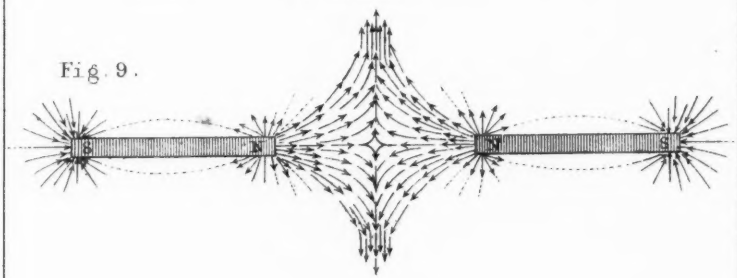
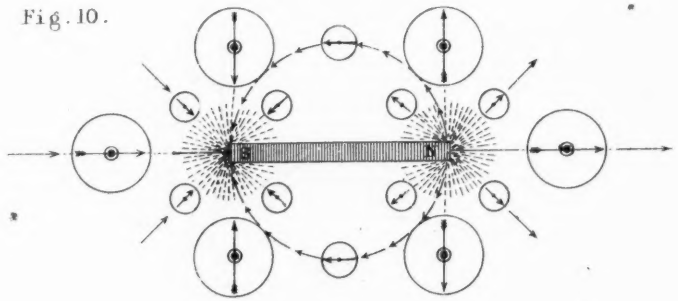
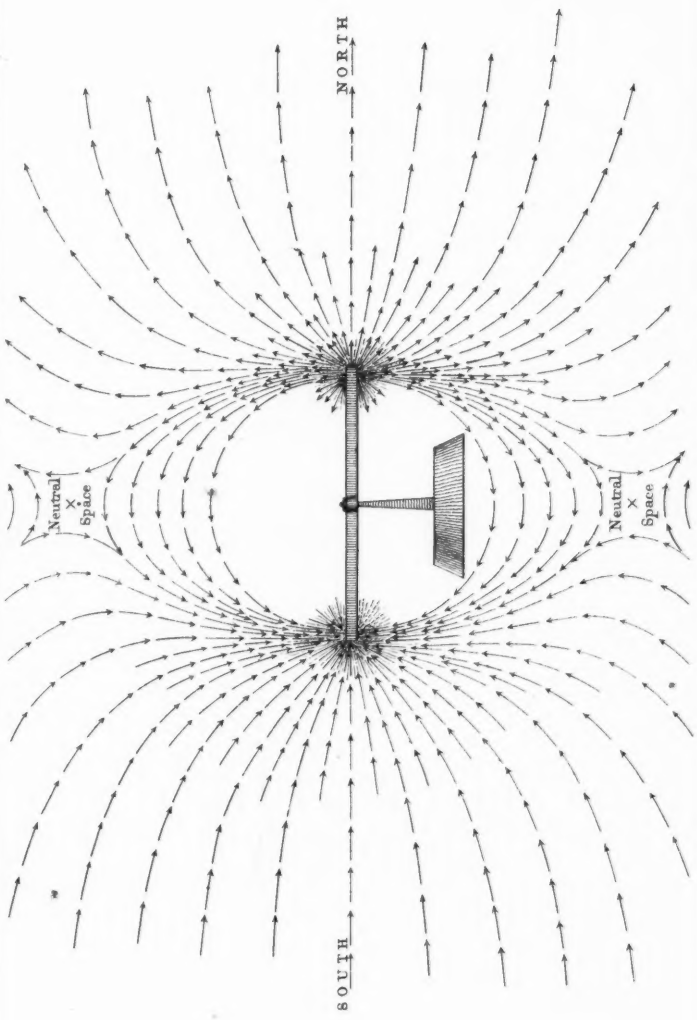


Fig. 10.



J.Jobbins

Fig. 6.



J. Johbins

Magnets surrounded by Iron-fillings.

Fig. 1.

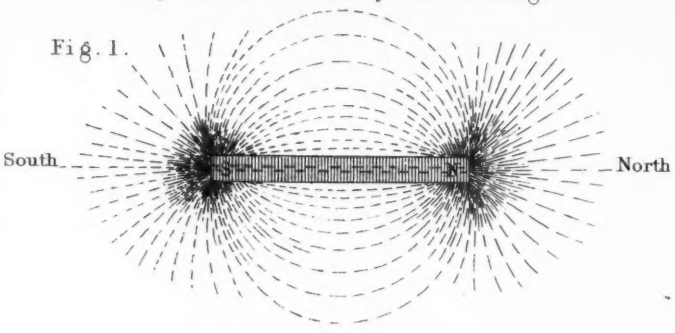


Fig. 2.

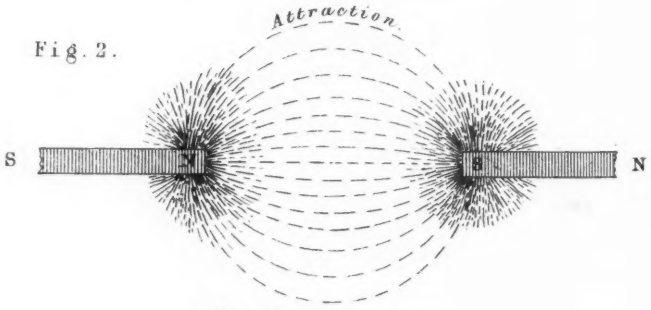


Fig. 3.

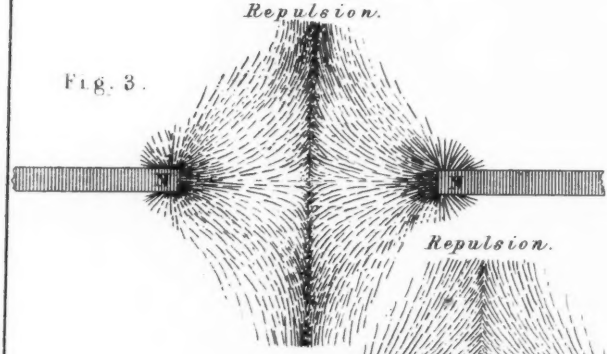
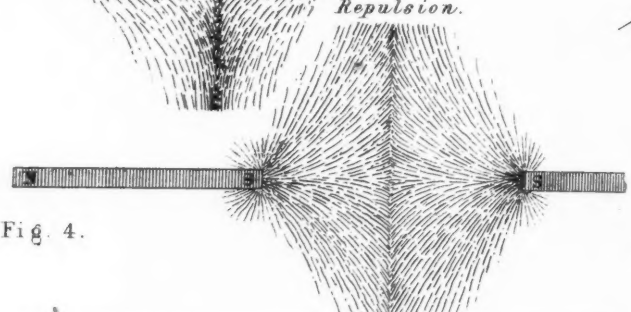
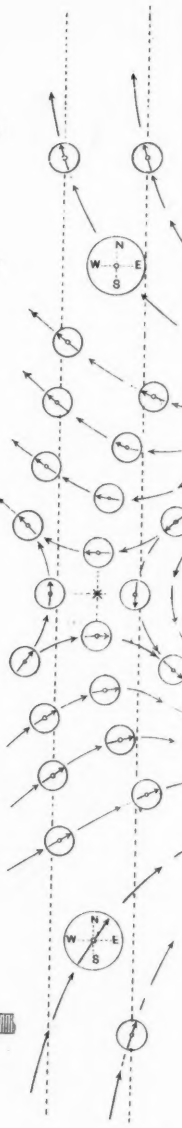


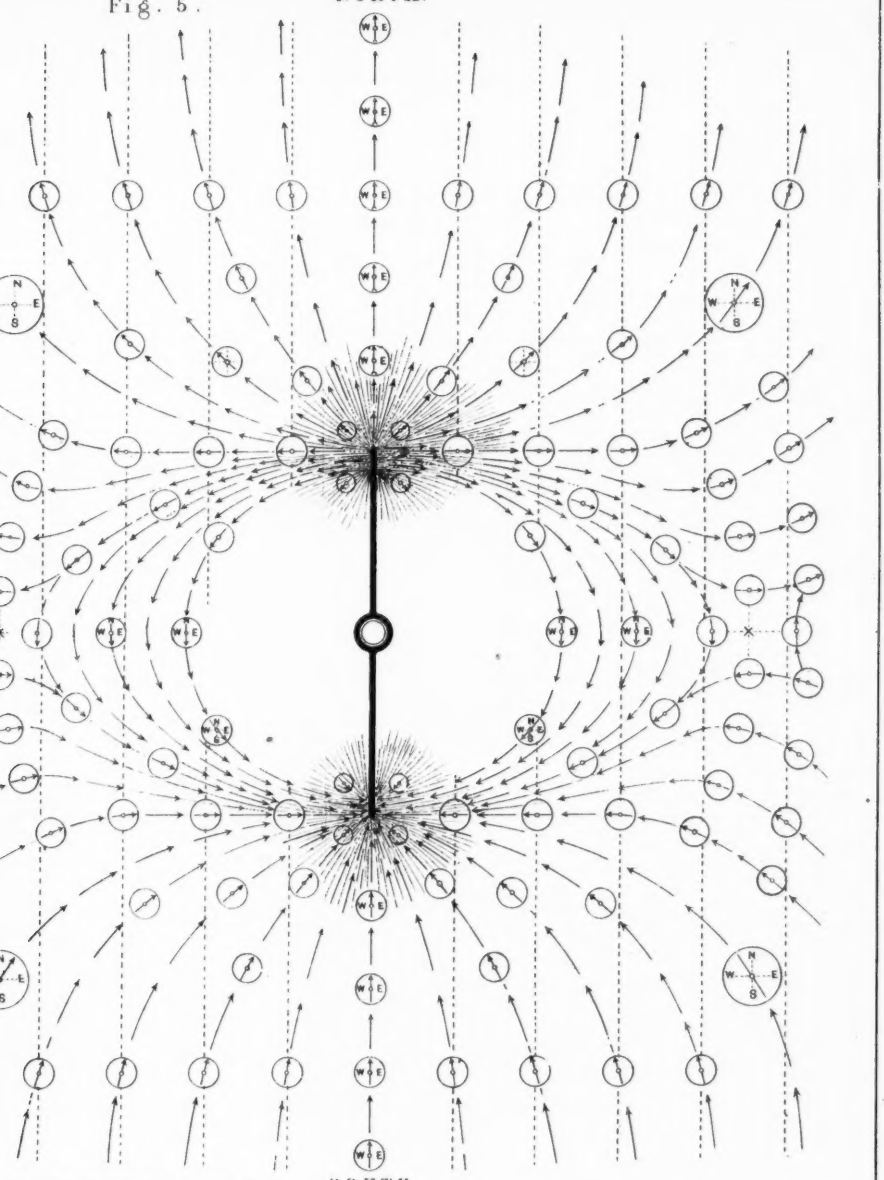
Fig. 4.





Note. *The Neutr*

Fig. 5.



The Neutral Points are marked ××

J. Jobbins

Evening Meeting.

Monday, January 29th, 1866.

REAR-ADMIRAL R. COLLINSON, C.B., in the Chair.

MEMBERS who joined the Institution between the 16th and 29th January, 1866.

LIFE.

Mouat, J. F., F.R.S., Surgeon-Major, H.M. Bengal Army. 9*l.*
Mease, Edward, Captain, Hon. Artillery Company. 9*l.*

ANNUAL.

Richardson, A. H. G., Lieut., R.N. 1*l.*
Townsend, S. P., Lieut., R.N. 1*l.*
Turnour, Edmond E., Commander, R.N. 1*l.*
Toppin, J. M., Captain, 2nd West India Regt. 1*l.*

TERRESTRIAL MAGNETISM WITH REFERENCE TO THE COMPASSES OF IRON SHIPS: THEIR 'DEVIATION AND REMEDIES.

By EVAN HOPKINS, C.E., F.G.S.

The CHAIRMAN: A paper will be read this evening by Mr. Evan Hopkins on Terrestrial Magnetism, as applied to the Compasses of Iron Ships. That subtle element magnetism, has baffled human ingenuity ever since it was first discovered. We have traced its forces, and we have connected it with electricity; but we have never been able to analyse it, and I suppose the power to analyse it will be hidden from us for some time yet to come. Mr. Hopkins, who has kindly consented to read a paper before you this evening, will explain some of the recent discoveries which have taken place. But his paper is

mainly upon that most important point of correcting the deviation in iron ships, so absolutely a necessity now that iron has become so much part of the material of our ships.

Iron Ships and Compasses.—Preliminary Observations.

Mr. Hopkins: The attention of the Fellows of the Royal Society has been recently directed to the very great increase which has taken place in the amount of iron employed in the construction and equipment of ships, and the consequent augmentation of embarrassment in their navigation by the action of the ship's magnetism on their compasses.

The deviation of the compasses, arising from the action of the iron, threatens to be productive of very serious loss of life and property, unless better remedial measures be adopted than those now applied. These inconveniences, which are now so much felt in the mercantile marine, have induced the President and Council of the Royal Society to forward a "Memorandum" on the subject, to the President of the Board of Trade, in which we find the following remarks:—

"It is believed that for some years the number of *iron*-ships con-"structed has greatly exceeded that of *wood*-built ships, and this is "particularly the case as regards passenger steamers."—"The conse-"quence has been a great increase in the amount of the deviation of "the compass, increased difficulty in finding a proper place for the "compass, and increased necessity for, and *difficulty in, applying to the de-"viation either mechanical or tabular corrections.*"

With regard to the science of magnetism, it is declared in the "Memorandum" that "at present it may be said that entire ignorance "of the subject is the rule." That "the most skilful seamen fre-"quently either ignore it altogether, or look upon it as a mystery not "capable of comprehension."

These statements from so high a scientific authority, in connection with many years of observations and experimental researches on the subject of terrestrial magnetism, have induced the writer to prepare this paper, at the request of the Council of this Institution, with the hope that it will render some assistance at least in the mitigation, if not in the entire removal, of the difficulties referred to, and in the carrying out of the objects recommended in the "Memorandum."

Mariners are well aware of the difficulty in applying to the deviation either mechanical or tabular corrections; the most careful and experienced navigators, place no reliance whatever on either of the methods now practised. As an apology for their ignorance of the science of magnetism, they declare that as yet they have had no books to enable them to acquire practical knowledge of the subject. "We do not "find," says an able writer on the mariner's compass, in the Quarterly Review of October last, "a single attempt at a popular "explanation of a branch of science which is quite capable of "being made intelligible to any man of ordinary capacity. Such "a work is much needed. The Admiralty Manual can only be "understood and appreciated by *mathematicians.* The work is not "adapted for the ordinary class of mariners, yet this is considered

"the best authority to which they are referred for information for "their guidance."—"A *popular* treatise is a desideratum, and until the "gap is filled up there is no prospect of seeing the principles of this "branch of science valued as they ought to be." *

With a view to aid in supplying this deficiency, the writer will give *a brief outline of the general character of terrestrial magnetism.* He therefore trusts that the phenomena of magnetism and polarity herein explained will be comprehended by practical men without much difficulty; so that they may obtain sufficient knowledge of the laws of magnetism, to enable them to apply them judiciously to compasses and other magnetic instruments, without the necessity of being trained in the *higher* branches of mathematics.

The Methods now Adopted to Correct the Errors of the Compasses in Iron Ships.

There are two modes now practised for correcting the *deviation*, each of which is considered to have its advantages and disadvantages; but excepting for ships making short voyages in the same parallel of latitude, both methods are regarded as mere temporary corrections; and even when confined to the same latitudes, they can only be depended upon for a very short time, owing to the rapid changes taking place in the *polarity of iron vessels.* These two modes are the following:—

(1.) For the ships of the Royal Navy, tables of deviations on each point are obtained by "swinging" each vessel before leaving port. The deviations recorded are applied as corrections to the courses steered. But as the *polarity* acquired by the vessel in building, is so transient that it diminishes very considerably in intensity in a few months—if the courses steered be subject to many changes, these tables for corrections made on leaving port become utterly useless, and often delusive and dangerous.

(2.) The system of "compensation" by magnets and soft iron is adopted in the mercantile marine. The navigating compass is usually placed in a position near the steering gear, where the deviation caused by the polarity of the axis is generally excessive. It is supposed that the compass can only be brought back towards its meridional direction by powerful magnets. When these magnets are applied, the compass is then held, as it were, in equilibrium by a powerful antagonistic force. And when the changes in the *polarity* in the iron ships, and in the *position* of the magnets with reference to the meridian, take place during a voyage, large errors are necessarily introduced which considerably aggravate the evil and thus render it advisable to remove them, to avoid fatal results.

If a compass be surrounded by fixed magnets, or even by ordinary iron, it becomes absolutely useless as a guide. An illustration of this has been observed in the "Royal Sovereign," where a compass carried into the interior of a turret was found to have scarcely any appreciable tendency to point in one direction rather than another. The same

* See "Quarterly Review"—Mariner's Compass, for October, 1865.—E. H.

kind of effect may be seen in placing compasses between iron decks, and in boilers, iron pans, or even in buckets; and also to a certain degree within a broad iron ring, or a cylinder.

It never seems to have occurred to the advocates of mechanical corrections, that the very same arrangements of iron and magnets which neutralise the ship's attraction, derange also the normal direction of the magnetic force; by which power alone, the needle receives polarity and is held in the magnetic meridian.

These attempts to correct the deviation, plainly show that the phenomenon of *the directive power of the magnet*, or the meridional force by which the magnetic needle is held in a north and south direction, is not well understood, and justify the remark made by the President of the Royal Society in the "Memorandum" to the Board of Trade, that "at present it may be said that entire ignorance of the subject is the "rule."

In corroboration of what has been stated relative to the *rapid changes* in the polarity of new iron ships, and the *difficulties attending the present methods* in correcting the deviation of the compass, the following instances may be noted:—

The "Scorpion," armour-plated ship, after lying *four months* in a contrary direction to that in which she was built, *lost much of her polarity.** Indeed all new iron vessels after launching lose a very great amount of the force of their acquired polarity, and therefore require much attention and very great care in the application of their compasses.

"To the application of any mode of correction by magnets or soft "iron to the *standard* compasses of the Royal Navy, strong objections "are entertained." "*The correction cannot be depended on in the case of* "*a newly-built ship.*" "There must always be great uncertainty as to "the correction on a change of magnetic latitude." "It is also right "that we should not pass over this remark without *protesting against* "*the application of such corrections to the standard compass.*"†

Yet, notwithstanding the objection and the protest, against the use of magnets, to correct the deviation, we are informed that the Superintendent of the Compass Department, in the absence of a better method, has not only been compelled to apply them to the steering compass, but also to *the standard* compass, especially on board the "Minotaur."

This fact alone shows the necessity of devising some new and less dangerous method of removing the difficulties, not only in the mercantile marine, but also in the Royal Navy.

A captain of an Australian iron ship, some years ago found, after crossing the equator, that the "*lubber line*"‡ was always nearly north by compass, in *whatever position the ship's head was brought!* The captain fortunately found out the fact, and its cause, in time, and immediately removed the magnets and then steered without difficulty. Indeed many

* See Paper by Messrs. Evans and Smith, read at the Royal Society, March 16th.—Postscript, page 321.—E. H.

† See "The Admiralty Manual."—E. H.

‡ Mid-ship line from bow to stern.—E. H.

similar instances have occurred in the Irish Channel, Mediterranean and Red Seas, Indian Ocean, and on the Pacific, of the removal of magnets to avoid confusion and danger.

It is no unusual thing for captains in getting to sea, to remove the correcting magnets, as they find that the changes of deviation in shifting the geographical position, are more uniform and more easily ascertained and corrected by observations in the *un*adjusted compasses, than in those which are surrounded by magnets.*

To guard against the danger of placing too much reliance on the present methods of correction, Mr. Towson, in his "Practical Information on the Deviation of the Compass," makes the following remark:—"The mariner should be cautioned not to depend on the adjustment "within half a 'point,' and to shape his course so that even a '*point*' "of error should not place him in danger." A "point" being 11 degrees, an error of half that amount in the Indian Archipelago, or even on the south-eastern coast of Australia, and other coasts with coral reefs, in a fast steamer, would be a very serious affair, especially in dark foggy weather.

The sluggish and incorrect state of many of the compasses of steamers employed in the English Channel and German Ocean, is lamentable. Had it not been for the fact that their commanders depend almost solely on the "look out" and the "lights," the consequences would be much more serious than they are. I lately saw in crossing the Channel a binnacle, which was placed within 3 feet of the heavy steering gear, repeatedly knocked and kicked to make the card move! The compass was scarcely 30 inches above the iron beams, and was surrounded by magnets and iron chains. In fact the compass was of no service, and in a fog would have been a source of danger.

Many of the errors of deviation attributed to the hulls of the ships, may be referred to the polarity of the steering axle, and the defective manner in which the binnacles are placed on board iron ships. This delicate and indeed very important part of the equipment of iron vessels deserves the serious and immediate attention of the Underwriters, as well as of the Board of Trade.

From the foregoing observations it is evident, that the present attempts to correct the deviation, and the mode of placing the compass on board iron ships, are extremely unsatisfactory, and tend to create confusion, and not infrequently lead to fatal results.

It will be necessary before entering further into the subject to give a brief outline of the phenomena of terrestrial magnetism, in order that its laws may be thoroughly comprehended. Without a knowledge of these laws it will be impossible to appreciate the merits or demerits of the various modes attempted and proposed to correct the deviation of the compass, which have been introduced and brought before the public from time to time.

* A new iron ship, employed in the Australian trade, has just returned to London; the captain of which, after leaving the Channel, found both the steering and the standard compasses so uncertain and erroneous, and also the table of deviation, that he was compelled to discard them altogether, and rig a compass on the mast about 20 feet high to navigate his vessel in safety.—E. H.

The Properties of Magnets.

The most obvious properties of the magnet are:—1. *Polarity;* 2. *Attraction* and *Repulsion* of other magnets at their respective poles; and 3. The power of communicating similar properties to iron and steel bars by touch or friction.

(1.) *Polarity.*—When a magnetic bar is delicately poised on a centre, so as to move freely in a horizontal plane, it will, after a few oscillations, assume a determinate direction north and south. This direction is called the *magnetic meridian.* The end pointing northward is termed its north pole, and the end pointing towards the south is designated its south pole.

(2.) *Attraction and Repulsion of other Magnets.*—If to a magnet placed on a centre we bring the pole of another magnet within a certain distance of it we find that their *similar poles repel*, and their *contrary poles attract*, each other. This is a well-established magnetic law.

(3.) *The power of communicating similar properties to other bars of iron and steel* by friction or touch.—If a bar of soft iron be placed at the end of a magnet it will immediately acquire *polarity* corresponding to the position in which it is placed. This polarity, however, is *transient*, and will only continue as long as the soft iron is under the influence of the magnet; but if hardened steel be placed in the same position it will acquire and *retain* the induced polarity. If magnetised to saturation the bar will be a *permanent* magnet, and will have the power of communicating similar properties to other bars of steel *ad infinitum* without causing the least diminution in its own magnetic powers.

The general conditions of a magnetic bar may be roughly illustrated by means of iron filings delicately strewn on a sheet of paper placed over the bar. The particles of iron will be arranged by the magnetic force surrounding the bar into a series of beautifully curved lines on each side, radiating outwards from the ends, as described in Plate I., Figure 1.

If the north pole of one bar be placed opposite the south pole of another, there will be an attraction. The curves of their mutual attraction are shown by the iron filings. (See Figure 2.) If the north poles of two magnets be placed in opposition, they will cause a strong repulsion; and if iron filings be strewn or sifted on a paper laid over their poles, they will represent the appearance of two brushes forced against each other at the ends of their bristles, as illustrated in Figure 3. Similar appearance is shown by iron filings in the repulsion of two south poles, as exhibited in Figure 4.

In order to render these phenomena of magnetic actions more clear and demonstrable, we must substitute for iron filings, a series of small compasses, placing them in various positions round a magnetic bar. By this means we shall be more able to trace the general character, and extent, of these curious magnetic curves, and the direction of the lines radiating at the poles.

Figure 5 represents the general character of the curves and radial

lines produced by the magnetic force of a magnet 6½ inches long. The small compasses, when undisturbed, point north and south in the direction of the parallel dotted lines,—but the moment a magnet is placed in the centre their direction becomes changed,—as will be seen on reference to the diagram, in which the lines are drawn strictly in accordance with the directions of the small needles.

The same kind of curves may be seen in the vertical plane, and can be traced by small dipping needles. (See Plate II., Figure 6.)

In a magnet 6½ inches long, ½ inch wide, and ⅛ inch thick, the radiating or fan-like lines at the ends of the bar, which are sometimes called "magnetic brushes," extend from the centre to a distance of about 2 feet 3 inches, and expand to a corresponding width at both ends. (Figures 5 and 6.)

The general appearances of these magnetic curves and radial lines, together with the mutual disturbances produced by magnets on each other, at a distance of 2, 3, and 4 feet apart, *indicate the existence of a subtle fluid passing through the bar.* The *centre* of the force moves in a direct line in the meridian, while the *external* part of the force continues to circulate and flow from pole to pole round the magnet.

Professor Faraday, in his brilliant magnetic experiments, found when the flame of a wax taper was held near the axial line between the poles of powerful magnets, that as soon as the magnetic force was exerted, *the flame receded from the axial line as if a gentle wind was causing its deflection,* thus indicating the presence of a subtle fluid.

Indeed, *a small needle can be retained in the centre of a helix of a battery without any apparent support.* This phenomenon can only be accounted for, by the presence of a potent magnetic fluid concentrated within the spiral by the electro-magnetic force.

On a line at right angles to what may be called the equatorial part of the magnetic bar is a *neutral* space, at a distance from the centre, equal to the length of the bar. This neutral space, in which a small compass loses its directive force, forms an equatorial ring round the bar, whose radius is equal to the length of the latter. (See Figures 5 and 6.) Neutral space marked thus +, +.

If a compass be placed within a broad iron ring or a cylinder, (although magnetism cannot be insulated) the iron will *derange* the uniformity of the direction of the terrestrial magnetic currents, and this derangement will necessarily disturb the normal *polar* action of the needle. The effect would be like placing a perforated screen round a wind-vane, which would admit the air, but would *alter the direction of the wind* and destroy its uniformity. It will be observed that the small compasses, represented in Figures 5 and 6, placed near the magnetic bars, are controlled by the curves and radial paths of the *artificial currents,* and not by the direction of the terrestrial currents; hence the *directive* property of a compass-needle may be compared to the indication of the wind-vane. The latter is made to show the direction of the wind, *the magnet,* in like manner, *indicates the direction of the terrestrial magnetic currents by the action of their circulation, and not owing to any inherent principle of its own.*

The Apparent Cause of the Attraction and the Repulsion of a Magnet at its Poles.

It has been shown, by means of iron filings and by small compasses, that a magnet displays a very beautiful series of curves or fan-like figures at the ends, which indicate the constant passage of the magnetic force, or current, from pole to pole.

We are able to ascertain the *direction* in which this magnetic current *moves* by means of percussion, and by electro-magnetic currents.

If we sharply strike with a hammer the end of a bar of soft iron, or a common kitchen poker, and make it vibrate from that end to the other, the percussion will induce a temporary *polarity*. It matters not in what position the bar is held, the effect is the same—*the end struck will always be its south pole.* It is, therefore, evident that the blows on the end of the bar, propagate a vibrating internal action from that end towards the other, inducing magnetic action in the direction of the vibration along the bar. If then we place the bar on a centre, it will take a meridional position, and *the end last hammered will point towards the south.* Hence, according to percussion experiments, *the magnetic force penetrates the bar from south to north.*

If we give a few blows on the opposite end, its polarity will be immediately reversed—*the end last hammered will always point to the south.*

The existence of this meridional force from south to north, penetrating the magnet, is further confirmed by electro-magnetic experiments.

By employing spiral coils and batteries of sufficient power, any steel bar may at once be magnetised to saturation. The *polarity* thus given to the bar *depends on the direction of the electrical current* with reference to the axis of the helix, or spiral coil.

In polarising by friction and percussion an *internal* current is generated, and made to pass through the bar from south to north. But when we polarise by means of a battery and a spiral coil, it is done by intensifying the action of the *returning external spiral currents* surrounding the magnet. The intensity of the magnetic force created by a battery, with a copper spiral coil, depends on the angle of the spiral with reference to the magnetic axis, and the number of coils applied. The finer the screw and the greater the number of coils, the more intense is the action through the magnetic axis.

The electric and magnetic forces are necessarily closely related. Although the one is exerted in a *spiral*, or obliquely to the movement of the other, yet their united actions are connected with the same centres of action.

The most powerful method of developing polarity in iron and steel, without the aid of ordinary magnets, is by means of the electro-magnetic spiral coil.

This brief description regarding the direction, in which the magnetic currents move, will be sufficient for the present to show, that the movement is *from south to north in the magnetic needle or compass.* It is im-

portant to bear this fact in mind, in order to comprehend the phenomena of terrestrial magnetism—*polarity*, *attraction*, and *repulsion*.

The magnet having acquired polarity from some mysterious changes in the internal molecular conditions, favours the passage or transmission of the surrounding natural magnetic force, from its south end towards the north end. This polar property of the magnet has the power of drawing, as it were, a volume, of about two feet in diameter, of the subtle magnetic fluid to its south end, which issues out again at the opposite north end, where it radiates and expands in a fan-like or brush-like shape to its original dimensions, as shown in Figures 5 and 6.

Hence the magnetic force, as it moves in the meridian, appears to converge at the south end of a magnet, and emerge again at the north end. Thus the needle is held and retained in the magnetic meridian by the northernly movement of the magnetic force.

If the *dissimilar* poles of two magnets be placed opposite each other, their mutual actions conform, and, consequently, there will be an attraction, as shown in Figures 2 and 8. Two *similar* poles will repel one another, the direction of the currents being opposed, as represented in Figures 3, 4, and 9.

The reason why iron filings or soft iron are attracted alike at both ends of a magnet is, because they are polarised on the instant of contact, and acquire the property which is possessed by a magnet of an opposite pole,—namely, an attractive polarity.

Soft iron, temporarily polarised, will attract and repel similar poles in *small* needles for a short time, but if brought near a powerful magnet, its polarity will be destroyed in a few minutes, or even seconds.

If a long magnetic bar be cut into small pieces without injuring its internal molecular conditions, each part will be found a perfect magnet. The transmission of the magnetic force in each part will conform with that of the original bar. This is proved by means of broken magnets.

Numerous experimental proofs could be given, to show that the magnetic force is transmitted from south to north through the magnet, and that its polarity, attraction, repulsion, and their curves, depend on the continuous action of the terrestrial magnetic force from south to north in the magnetic meridian. Hence the magnetic force appears to enter the south end, penetrate the magnet, to emerge again at the north end, and so to proceed in its everlasting circulating course over our globe from pole to pole.

Terrestrial Magnetism.

It is well known that if a bar of iron be placed in the direction of the magnetic meridian, and be left in that position for a certain period, it will acquire *polarity* from the magnetic currents of the earth. This effect is not confined to bars of iron, but is also observed, in a greater or lesser degree, in all ferruginous rocks in the primary formation. The *loadstone* is an oxide of iron found in the crystalline rocks. It is a natural magnet, capable of retaining its polarity like hardened steel. Oblong pieces of compact ferruginous rocks, like loadstones, if delicately suspended, or made to float on quicksilver, will point north and

south, like the magnetic needle. *It is also a remarkable fact that this polar direction corresponds with the meridional direction of the same rocks in situ.**

Hence from these facts and numerous others which might be mentioned, the earth may be regarded as a spherical magnet, with a powerful magnetic axis in its centre of rotation. This magnetic axis necessarily causes a universal circulation of its currents from pole to pole; and as these currents are found to move from south to north, the action of the north pole of the earth corresponds with that of the south pole of a magnet, *i.e.*, is an absorbing pole, towards which the currents converge into the axial focus.

"True as the needle to the pole" is an old saying, which requires qualification. It is true that the magnetic needle, if not disturbed, points more or less towards the polar regions, but not strictly to the centre of the terrestrial poles, and much less to the so-called "magnetic poles." The direction of the magnetic needle is not dependent on the centre of the magnetic axis, but on the *local bends* in the circulating path of the terrestrial magnetic force.

It cannot be expected that the magnetic meridians of our globe should strictly coincide with the true meridians as seen on an artificial globe. The various atmospherical changes, oceanic movements, and geological disturbances, &c., would preclude the possibility of such uniformity in the direction of the force from south to north. Notwithstanding these disturbing influences however, the meridional action, or the movement of the terrestrial currents from pole to pole approximate, as a whole, so closely to the true meridian lines as to entitle their paths to be called the "magnetic meridians." They converge within the Arctic Circle, and reasoning from analogy, founded on experiments on the observed "dip," compared with the needles on an artificial globe, the end of the terrestrial magnetic axis must be at least 20° in diameter.

It is a great mistake to suppose that a magnetic pole is a mere mathematical *point*. There is nothing in the laws of magnetism founded on direct observation on artificial magnetic globes, or in the earth itself, to warrant such an assumption.

It is generally supposed that a magnetic north pole has been discovered, in latitude 70° in the western hemisphere, because a dipping needle was found to approximate to an angle of 90°. Magnetic dipping needles would necessarily assume a vertical position over the *whole area* of a polar axis,—like pins in a pincushion,—and not over *one mathematical point alone.*

If the observed *magnetic meridians* be extended into the arctic and antarctic circles, it will be plainly seen that, as a whole, they converge towards the *centre of the polar regions*, and not towards the so-called "magnetic poles."

The charts of "variations" are not made to represent the *direction of the magnetic force.* The lines are intended to *connect points of equal degrees of magnetic variation.* For the study and proper comprehension of the phenomena of terrestrial magnetism, charts representing the *undu-*

* This subject is fully explained in "Geology and Magnetism," 3rd edition. Francis & Taylor, Red Lion Court, Fleet Street.—E. H.

lating direction of the magnetic force from pole to pole should be prepared. According to observations, the greatest "variation" from the true meridian is in the northern part of the Atlantic between Europe and North America. In the Eastern Hemisphere, from Tasmania to the Arctic shores of Siberia, the *magnetic meridians* more or less coincide with the *true meridians*. They commence to deflect towards the west in the Indian ocean, Africa and Western Europe, as will be seen on reference to the maps. The "variation" in the Pacific, as a whole, deviates but slightly towards the east.

It must be borne in mind that the charts of "variations" are not by any means strictly correct *inland*, more especially in Africa, Southern Europe, and America. Again the "variation" is perpetually changing, not only inland, but also along coasts, and in Archipelagoes. The writer detected an alteration of 2° 30′ in an easterly variation which had occurred during 15 years on the Western Andes.

The mariner may in mid-ocean take the chart of variation as his guide, but in approaching coasts, and especially the South-East Coast of Australia he must be watchful, and be guided by direct observations, as the *undulations* of the magnetic force (by which the compass is directed) are very variable.

The deviation of the compass from its normal direction is not caused by any local attraction acting *directly* on the needle. The *needle itself* cannot be affected by any local attraction of an island or a coast. It is the *undulation* of the magnetic force, that disturbs the action of the needle. This disturbing influence may occupy a width of many miles along a highly ferruginous coast.

We have shown that the globe is a natural magnet, with a magnetic axis, and that its magnetic force or circulating currents move from south to north, and complete the circuit of their activity through the medium of the magnetic axis, in the same manner as observed in an artificial globe. All magnetism is derived directly or indirectly from the magnetism of the earth. This natural force will polarise a steel bar, and convert it into a needle for pointing north and south, if left to its sole controlling power, and free from local attraction, and will render it a permanent magnet, like the lode-stone.

Deviation of the Compass.

"Deviation of the compass" is a term now used to denote the error of the compass, caused by the attraction of the iron of the ship, whether that iron be employed in her construction, in her equipment, or placed on board as cargo.

Iron ships, like iron bars and girders, if constructed or placed for a certain time in the meridian, and more especially if subject to hammering and rivetting, will acquire *polarity*. This polarity will necessarily affect the compass, and cause a deviation, from its proper direction, to a degree proportionable to the amount and proximity of the disturbing cause.

The *permanency* of polarity, however, depends on the nature of the

iron. It is only when iron is converted into *steel, and then hardened,* that it becomes capable of retaining *permanent polarity.*

The general character of the iron with which a ship is constructed, possesses little of those qualities which are essential for the production of a *permanent* magnet. Consequently permanency of polarity could not be anticipated in any iron ship, but it may take some years before it vanishes away.

When a ship is removed from dock, and its position with reference to the meridian reversed, if it be again subjected to hammering and rivetting, the polarity acquired when in the dock would be altered and partially destroyed.

As the *acquired polarity* of an iron ship from induction and position is generally acknowledged to be the principal cause of the "deviation," and of the danger attending the sailing of a new iron ship, *the writer recommends the application of an electro-magnetic battery to destroy the ship's polarity immediately after launching or before leaving the dock.*

It is an ascertained fact that we can polarise any symmetrical bars, plates, or masses of iron, and reverse and destroy that polarity, instantaneously, by means of a powerful battery. I have made experiments to prove this fact. I have therefore no hesitation in stating that, by means of proper and suitable appliances, the acquired polarity of the largest iron vessel can be destroyed before leaving the dock, and thus reduce the disturbing action of the iron on the compass to its ordinary normal state. Instead of attempting to counteract the effects of the polarity of the vessel by means of fixed magnets, the depolarisation will remove the disturbing cause altogether, and thus put an end to all the embarrassments. I am quite prepared to carry out and practically establish this system of depolarising iron ships.

If then the *polarity* of the iron ship be thus destroyed, it follows that it matters not, in what direction the vessel might be constructed. When the induced polarity is neutralised or destroyed, the necessity for "swinging," and the making of tables for correcting the "deviation" arising therefrom, will be obviated, and the main cause of the existing dangers attending new iron ships from the errors of their compasses, will be removed.

On the Position of the Steering Compass on board an Iron Ship.

The *directive property* of a magnetic needle, as already stated, depends solely on the direction of the terrestrial magnetic force. If, therefore, the latter be affected by any disturbing influence, the former cannot retain and preserve its normal meridional position. This fact does not require further explanation, as it is capable of being easily proved by very simple experiments.

It follows from this that a compass for steering correctly, should be placed in such a position on board a ship, as would preclude the possibility of any disturbing action from the steering gear, and other iron, employed on board. Precautions are taken to construct the binnacles of wood and brass, and to avoid iron, but seldom any regard is paid to the *position* in which the needle should be situated. Unless the com-

pass is placed several feet from iron (even in its normal state), so as to be free and beyond the reach of local attraction, it cannot conform to the meridional prime mover.

In merchant ships the steering compass is generally placed near the stern-post, the rudder-head, the tiller, and the iron spindle of the steering-wheel,—all of which are more or less polarised. This is a position where the local attraction and disturbances are often excessive and changeable, and in which no navigating-compass should be placed.

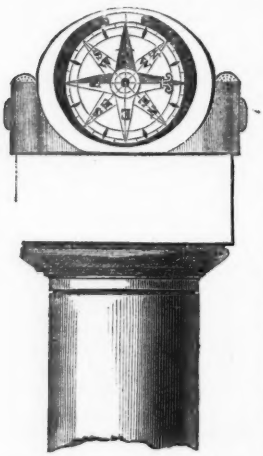
In the "Memorandum" of the Royal Society it is "recommended that every iron passenger ship should be required to have a *standard compass*, distinct from the steering-compass, in a selected situation at a certain distance from all masses of iron;" "and to use this as the navigating-compass, prohibiting the use of a steering-compass."

If the incorrect steering-compass be not taken away, and some convenient arrangements made, by which the steersman can steer by looking at the standard, the evils will not be removed. A wreck has recently occurred of an iron steamer, in which was placed a standard-compass twenty feet high, fastened to the mast, free from all attraction, and found to be exceedingly correct. The steering-compass, on the other hand, was surrounded with strong magnets and iron chains, and consequently rendered uncertain in its movements and direction; yet the latter was used for steering! In the Merchant Shipping Act it is provided that "every sea-going steamship employed to carry passengers shall have her compasses properly *adjusted* from time to time," &c. Strictly speaking, compasses *cannot be adjusted* or be made to act correctly by any artificial contrivances, as already demonstrated, and, therefore they should not be tampered with. It should be provided that every sea-going steamship employed to carry passengers, should have her steering-compass placed at a certain distance from the steering gear and from all masses of iron, and such arrangements made, as would enable the helmsman to see the compass-card, like the dial of a clock, many feet above the deck. This is the only way to remove the danger, as it is well known that steersmen will only be guided by the steering-compass, and not by the standard, the latter being generally very inconveniently situated for the man at the wheel. Large sums are often spent in ornamental brass binnacles, chain boxes, magnetic compensators, whilst the compass is placed in a changeable magnetic medium. The gimble-box might be raised at a small cost on a high wooden post, or fastened to the mast from 10 to 20 feet high, and thus be free from all the ordinary disturbances of iron in its normal state; it could then be depended upon for steering. The outlay would be slight, and the benefit very great. Two compasses might be placed on the mast, one on each side, about 6 feet apart, with their cards seen like the dials of clocks, and illuminated at night, so as to be plainly read by the steersman.

By means of this arrangement the helmsman would have the constant and full benefit of a standard-compass to steer by, which cannot otherwise be ensured in stormy nights in the mercantile marine, whatever they may do in the Royal Navy.

Many thousands of pounds are most liberally expended, even on the ordinary fittings of iron vessels, their decorations, and also in a number of ornamental binnacles, yet their compasses frequently vary in their direction from one to two points, owing to the bad and very inconsiderate *position* in which they are placed. In some of the steamers running between England and the Continent, the binnacles, as already stated, are within thirty inches of the steering gear and the deck beams. The steering compasses are then sometimes so incorrect and sluggish, as to require the "watch" to hammer the binnacles to make the cards move. It is time that such a state of things should be more generally known and corrected for the safety of ships and passengers. If, as I recommend, we first remove or destroy the transient polarity acquired by an iron-ship in building, and then place the compass-box from 10 to 20 feet high, either on a post or against the mast, as may be found most convenient, the entire difficulties arising from "deviation" will be got over.

Fig. 13.—Binnacle showing the Card by reflection.



There are several modes by which the compass-cards may be rendered visible and easily read at a high elevation above the steering-wheel, which I need not describe on this occasion.

It is sufficient, at present, to indicate how the difficulties from deviation may be overcome by depolarisation and by placing the steering-compass at a higher elevation, and in such a position as would allow it to be under the sole control of the earth's magnetic force. This is the only method by which the compass can be made to act correctly, and retain its meridional direction on board an iron-ship.

The Vibrations of Compasses.

The vibrations of the common *flat* needles, which are generally used in ordinary vessels, are excessive. Their frequent unsteadiness during stormy weather renders it difficult to steer correctly. In the third report from the Liverpool Compass Committee to the Board of Trade, we find the following remark:—"The agate cup in which the pivot "rested had been filled up with brickdust, for the purpose, it was "stated, of steadying the card, so that, when examined, it was found "that the vibration from the screw and the grinding of the brickdust "had made a hole completely through the agate!"

The general impression is, that excessive oscillation can only be diminished either by an increased *friction* or *increased weight*. Hence, heavy brass cones (called bells) are screwed under the centre of the needles, the weight and the shape of which make them steadier and reduce the number of oscillations.

The fluid-compass is another contrivance to check vibration and to ensure steadiness in the action of the card.

Had the laws of magnetism and the mode in which the magnetic force acts on the needle been better understood, the troubles attending *excessive* oscillation might have been obviated without increasing the friction or the weight, as will be observed by the results of the following experiments.

The following needles were placed, in succession, to oscillate from E. to W. on the same pivot. They were drawn delicately, by means of a magnet, from their line of rest in the magnetic meridian, to an angle of 90°, say E. or W., and then allowed to oscillate until they returned and remained at rest in their original position. They were protected from all external disturbance by a glass shade cover.

All the needles were of the same length, viz., $6\frac{1}{2}$ inches long.

The following results were obtained :—

	No. of vibrations.	Time occupied.
Flat needles $\frac{1}{8}$ inch wide, and $\frac{1}{10}$th inch thick, made ..	60	420 seconds.
The same size needle placed on *edge*	20	175 „
Edge needle of the same weight, but thinner and broader ($\frac{2}{3}$ths of an inch deep)	14	104 „
Edge needle, very thin, $1\frac{1}{2}$ inch deep.....	12	90 „
Ditto, angular needle, with a conical card.....	10	70 „

By placing the needles on *edge* instead of *flat*-ways we not only check the tendency of excessive oscillation, but also increase their directive power, and thus make it coincide more accurately with the magnetic meridian.

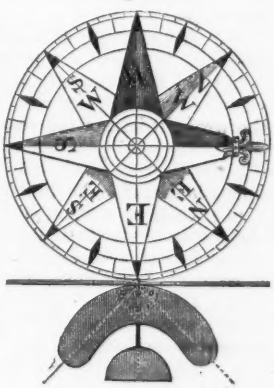
It therefore follows that compass-needles, to insure steadiness of action and strong directive power, should be made thin and broad, and to hang on edge, and that flat needles should not be used for steering purposes.*

The *double-bar* cards are steadier than the single-bar cards, even when of equal weight, and possess a stronger power of retaining their meridional position when exposed to local attraction and other disturbances. The compound magnetic polar "brushes" expand and increase the extent of the circulating currents, as will be seen on reference to Figure 12 Plate IV. Consequently the directive power has a longer meridional range. The neutral ring is also greater in proportion than that surrounding a single-bar card. See Figure 11.

A card with double-bars $1\frac{3}{4}$ inch in width is very sensitive and powerful in its directive force.

These broad needles may carry a

Fig. 14.



* This refers to *straight* flat needles.

card like a circular band, with the cardinal points marked thereon, so as to be read at a distance. (Fig. 14.)

Bent or Curved Compasses.

It is well known that the *straight* horizontal needle becomes sluggish, indeed totally inactive and useless, and therefore unfit for steering in very high latitudes, consequent upon the rapidly increasing dip of the magnetic force as it descends towards its polar focus. Indeed a *straight* needle, strictly speaking, is only adapted to the equatorial zone, where the magnetic force conforms with the tangent of the earth's circumference: the magnetic force acts very obliquely in the northern and southern hemispheres. Even in the Gulf of St. Lawrence, in the parallel of about 50° N., the dip is 78°, consequently the ordinary compass cards become very uncertain in their direction from the sluggishness of their action and the weakness of the directive force of their needles, from their non-conformity with the direction of the terrestrial magnetic force. This defect, occurring in a region in which fogs prevail, and consequently where a vessel must depend entirely on her compasses, unusual loss of ships is thereby caused in that quarter of the globe. To remedy this evil I propose to bend the needle into a curve, terminating at the ends about the average angle of the dip. The curved needle will act freely, with a much stronger directive force, in high latitudes than the straight needle. Even a *flat* needle, if *bent to the angle of the dip* at the centre, will not only have its directive polar power increased, but its vibrations will be reduced to one-third. The compass-needles of all ships confined to the northern hemisphere should have their north end bent to the angle approaching to the "dip," to obtain the maximum magnetic force.

I shall now briefly recapitulate the remedies proposed, for removing the difficulties connected with the disturbances of compasses on board iron ships.

(1.) To neutralize or destroy the *polarity* acquired by an iron ship in building, by means of a powerful electro-magnetic battery.

(2.) To raise the steering compass to such an elevation as will place it beyond the reach of the influence of the ordinary attraction of the wrought iron of the vessel.

(3.) To place a reflector near the compass, so that the card may be seen like the dial of a clock, and correctly read, at a distance of 20 feet and upwards from the steering-wheel.

(4.) To place a dumb card in front of the steering-wheel, for setting the course of steering, for the guidance of the helmsman, so as to avoid mistakes from verbal directions. The compass-card and the dumb-card of course being made to correspond with one another.

(5.) To make and apply such compass-needles as I have described, of the strongest directive power, so as to avoid unsteadiness and excessive oscillation.

(6.) To employ *bent* or curved compass-needles adapted for steering in high latitudes, where straight needles are found sluggish in their movements, and necessarily often incorrect in direction.

In conclusion I would beg leave to observe, that in these days of general intercourse and competition, when all the people of the earth

are launching forth to meet us on the great oceanic highway of commerce, we should not only foster and encourage the skill of our seamen, but also provide them with the best appliances and nautical instruments which this scientifie age can produce. The anxiety and dangers attending the seas are sufficiently great at best, under the most favourable conditions. It is therefore our duty to do all we can to mitigate them, and especially in vessels employed to carry passengers. The first and most important among the requirements of a ship's instruments, is a compass which will at all times conform with the magnetic meridian. A chronometer is as dust in the balance, in comparison, because, in most cases, its results are only relied on when danger is not apprehended. Therefore it is as imperative to provide a proper place for the steering compass, as it is for the rudder, and it is quite time that this subject was brought more rigidly under consideration in all iron-vessels intended to carry passengers, not only in long voyages, but also in vessels employed in the channels.

Absolute freedom from all dangers from inconstant "variations" may not be attainable; it is, however, in our power to modify and remove a very great portion of the existing difficulties and dangers connected with compass errors, and relieve the mariners of a very great amount of their present anxieties, and thus reduce the number of those formidable risks and deplorable wrecks, which may well make us tremble for the safety of the vast fleet of iron vessels, with the inestimable amount of lives and property now constantly afloat on the ocean.

The CHAIRMAN: Perhaps some gentleman would like to put a question to Mr. Hopkins with respect to the explanation of something that he has said.

Rear-Admiral Sir EDWARD BELCHER, C.B.: Mr. Hopkins has advanced the statement that there is no magnetic pole. Now, I have been on three sides of the pole and made observations with a most delicate dipping-needle, the beautiful dipping-needle of Mr. R. W. Fox, which was supplied to me by the Royal Society. That instrument would detect a minute of dip at any position by the beautiful method of the deflectors. The instrument shown by Mr. Hopkins would not give any result whatever in Polar latitudes! Therefore, having been north-east, north, and north-west, and Admiral Kellett having used his dipping-needle very far west, at Melville Island, we know to a certainty that there must be a magnetic pole; and James Ross certainly found it. He searched for the magnetic pole by using a similar dipping-needle, round in all directions, and calculating where the determinations pointed to. His was a similar dipping-needle to mine, by Fox, and he was able to determine the *exact spot*. In the same manner he determined the South Antarctic Pole. He was fortunate enough to discover both those. But the variation and the amount does not run in parallels. For instance, if we go from Gibraltar in 32° 22″N. we find there that we have a pretty considerable variation; if we run west to Bermuda we find we have none; and if we go a little further in towards the American coast, there it increases. Then, again, in the Pacific we find that there are pear-shaped spaces, if we had a magnetic chart you would see them marked, where there is no variation whatever; but as you travel either north-east or south-west, you increase your variation from that spot. There are several of these places on the earth's surface. But we now come to this question of the local attraction. In the year 1830 I ventured to try a similar theory to this by having an electrical medium to surround my compasses. This I could do at pleasure in my cabin, and could rectify the needles by an electric atmosphere, and give the true direction to those on deck. But when we come to wooden ships, this theory of Mr. Hopkins is not of the slightest value; you cannot take the magnetism out of a wooden ship. It is there local attraction. In the case

of the "Blossom" we went up Behring's Strait, as Admiral Collinson will tell you; and when we got up to Icy Cape we found, with the head W.S.W., 22½° of variation. We tacked E.S.E., and there were 56° of variation. It is perfectly absurd to talk of taking the magnetism out of a wooden ship in that way. With regard to the point where Mr. Hopkins is in unison with my own idea, I communicated it to him some years ago, at the time we had that fight with Dr. Scoresby.

Mr. HOPKINS: Yes.

Sir EDWARD BELCHER: Scoresby said an iron vessel leaves the dock with a certain polarity. She meets a sea, she gets a slap in the face, and by percussion it is all gone. But as soon as you have deprived a vessel of all the polarity she got in dock—(I will allow that you can deprive her of it, which you can do with the greatest ease, because you know we can carry a message from here to America, and we can take the magnetism out of a ship by a similar process)—but having taken it out, you have soft iron still, and that soft iron will have its influence on the needle. I admit you can take out all the induced magnetism from the ship. No doubt the rivetting produces an immense amount of it; but as I say, the moment she meets a sea, and gets two or three slaps by the sea, the half of that is gone; but the soft iron still remains. I thought Mr. Hopkins was going to inform us to-night how, within the short space of a circle of three feet, he would literally get the compass to point the same as if she were not in an iron ship. I believe he could do it if he pursued the investigation further. I have had the idea in my head since 1830. I believe if you can produce a ring of electric power, surround the needle with an electric atmosphere, that you will cut off all the influence of the polarity of the ship. There is only one other remark I would make, and that is about the bent magnet. Mr. Hopkins does not seem to be aware that ships navigating in high latitudes use a dipping-needle compass, and that dipping-needle compasses answer all the purposes of Mr. Hopkins' instrument. But, then, when you come to deal with the dipping-needle compass, you must consider that the force is in concentric rings, and according to the dip you have decreased the power upon the leverage of your magnet, equal to the smallest concentric ring it makes, that is, the lower end of your needle, measured from the vertical, is the only force you have the co-tangent of the dip. The force is not in the line of the needle; it is in the *base* which corresponds with the hypothenuse from the perpendicular.

Captain FISHBOURNE, R.N., C.B.: I think we may congratulate Mr. Hopkins, notwithstanding Sir Edward Belcher's remarks, upon having set the egg on end without breaking the shell. Sir Edward Belcher's observations are just the opposite of Mr. Hopkins'. Sir Edward Belcher is in favour of employing means to correct errors; Mr. Hopkins, on the contrary, would do away with the cause of error. With respect to the magnetic poles, that is foreign to the really practical part of the question; but then, in that Sir Edward Belcher is incorrect. A dipping-needle will not indicate the position of the pole, because it revolves upon a fixed axis, which will maintain it in a particular direction, and prevent its indicating lateral deviation. It can only travel in the vertical plain, and therefore, can only measure the dip, and not the deviation. However, it is quite foreign to the subject. In my opinion the plan of Mr. Hopkins is eminently practical; there is nothing theoretical about it. Though Sir Edward Belcher has given you a theory, this is not one—this is practical. Mr. Hopkins shows you that he measures every line of magnetic influence, and that anybody may repeat his experiments for himself. Its great value appears to me in doing away with all corrections, because there can be no question, that though you may thus reduce the error, you really reduce the value of the compass in that same degree by reducing its directive power. If it has no directive power, it is of no value whatever. Any person who is acquainted with, or has been in, certain difficulties, knows how important it is to get a ship round to a given point. Take the case of a man overboard at night time. It is very desirable to know the course you have been steering, and to retrace your steps and go exactly back again. Well, your ship is swung round; but if your compass is sluggish, you will be steering altogether in another direction, and you may lose the man's life. Again, suppose you have been steering into danger, you are in the dark, and you are desirous of steering back as your only course of safety. You came in without harm, and if you can go back again exactly

you will be in safety; but if your compass is sluggish, you will not know when your ship is round, and you may steer into danger.

It is perfectly evident from this system, as shown, from the table of the oscillations of the needle, that the proposed arrangement of Mr. Hopkins will be attended with considerable advantage. He has reduced the period of time wherein the needle returns to rest from 420 seconds to 70 seconds, and the oscillations from 60 to 10. One can understand at once the immense results that are arrived at, while all the systems that have been introduced to reduce the oscillations have been only more injurious. For instance, they sought to reduce the oscillations by a copper ring by an electric galvanic action. But there, again, you interfere with the value of the compass, as with regard to the needle you reduce its directive power, and therefore its value. Here, on the contrary, Mr. Hopkins dispenses with all these, puts them aside as injurious; and he intensifies the magnetic power of the magnet, and so induces a power, the value of which it is hardly possible to measure. Then, again, I think he has given us a practical reason, and a very sensible one, for the introduction of that shape of card, to dispense with the steering compass, and to make the standard compass your normal compass, the compass by which you may steer under all circumstances. Commodore Ryder and others have introduced tables on which to record the differences between the standard and steering compasses on each point, but we know that these complications are dangerous. So are all your corrections when you do not know how to apply them. It is better to know that you have an error, and that that error is always to be watched, than to assume that you have got rid of all errors, and know that, notwithstanding that, every change from accidental circumstances, steering upon one particular course in a different direction from that which the vessel has been built in, steering on a multiplicity of courses, all these will have different degrees of effect. You have no way of measuring the amount of error that is introduced by these varying circumstances. You are always at sea, and the result is that while you are always at sea you are very likely to get on shore when you least desire it.

Admiral OMMANNEY: I think I heard Captain Fishbourne state just now, with regard to fixing the locality of the magnetic pole, that he would ignore the use of the dipping-needle.

Captain FISHBOURNE: I said that no dipping-nedle would establish that the pole was practically a point.

Admiral OMMANNEY: Sir James Ross, with a dipping-needle, fixed the position of the magnetic poles; and the researches of subsequent explorers with the dipping-needle, passing from the easterly to the westerly variation, passing that point where the compass pointed 180°, which I have done myself, tended to confirm the position of the pole as it was so accurately determined by Sir James Ross. We must have all listened with pleasure to the clear manner in which the lecturer has illustrated the subject this evening. All I have heard from him only confirms in me the necessity of watching more strongly, and observing those regulations which have been pointed out by the Admiralty. I think there is a discussion between the Admiralty and the Board of Trade; I can only hope, that it will induce the Board of Trade to carry out the regulations made by the Admiralty, and suggested by the Royal Society; it would be of the greatest advantage to the country, for ascertaining the correction for compass errors and deviations.

J. REDDIE, Esq.: With reference to this observation of Admiral Ommanney,—it was stated in the *Times* of Friday last that the Board of Trade had refused to adopt the suggestions of the Royal Society; and I believe the Committee of Lloyds have signified their perfect approval of the course pursued by the Board of Trade. With reference to one or two remarks which Sir Edward Belcher made, I think there is some misunderstanding on his part, as regards Mr. Hopkins' view of the terrestrial currents. He (Mr. H.) said that the magnetic currents did not correspond precisely with the meridian lines; and he endeavoured, as I understood his paper, to explain that these deviations were attributable to the nearness of the land, and to the particular formation of the rocks in the neighbourhood.

Sir EDWARD BELCHER: East and west of the parallel, not vertical.

Mr. REDDIE: Quite so. Then Sir Edward made some observations about wooden

vessels. In the present day, the difficulty, as far as I understand the question, is not about the wooden vessels. It is about iron vessels. Sir Edward quite agreed with the author of the paper as regards the possibility of destroying the polarity which the vessels attain from their position in building; yet it is a very curious thing that nobody before thought of destroying this polarity in such an effective manner; at least it has never been done. Certainly, what Sir Edward said about surrounding the compass with an atmosphere of electricity is just the opposite mode that Mr. Hopkins proposed. In fact, if there is one weak part at all in the author's proposition, it is simply that he has almost, I was going to say, proved too much. Sir Edward Belcher has proved too much when he made the difficulty about the wooden vessels. I think Mr. Hopkins has almost proved too much in another direction. For his practical proposal is this, that you should dispense with your bad compass, and steer by your standard compass. If there is any justification at all for a standard compass on board ship, this proposition of Mr. Hopkins is thereby established, for he wishes you to have your sole compass a standard compass. And, as he has got his compass entirely out of the power of the artificial polarity of the vessel, or even of its soft iron after the polarity is destroyed, I think that it is almost of no consequence, whether you destroy that polarity or not, so that you have your compass 20 feet above deck, and can have a compass with a reflector such as he has shown, or with one of those crowns, by which you can see it at a distance, and steer by it. Surely, it stands to reason, as we know that sailors steer by the steering compass, and not by the standard, though the standard is the safest, that if you can get rid of the uncertain compass and steer by a safe one, then that is the best way of carrying out the spirit of the Admiralty directions on the subject.

Captain SELWYN, R.N.: I, in common with others who have spoken, recognise the very lucid manner in which Mr. Hopkins has put the subject before us. But I venture also to dissent from some of his conclusions, principally those which affect the use of the compass on board ship. Now, with regard to the use of the binnacle and standard compasses, I think most of my nautical brethren will agree with me that the great reason why we retain the binnacle compass is, not because we have any opinion of its accuracy, nor do we desire even that it should be accurate; that is quite a secondary consideration with us. We do not care whether our watches mark Greenwich time or not, so long as by our chronometers we can get at what Greenwich time is. The binnacle compass is used like the ordinary watch in taking sights, as a mere means of comparison. It may be half an hour out, and yet it is just as correct for our purpose as if it were absolutely showing Greenwich time, because we have Greenwich time to compare with it. Now that Greenwich time in the case of the compass is the standard compass. It has always been the object, in every case, of the Compass Committee to place that standard compass as carefully away from all sources of error as it could be done. In the nature of things, unfortunately, it is very difficult of attainment in iron ships; and Mr. Hopkins has so far eliminated a portion of the difficulty, that he has shown us that we may immediately, on leaving port, have a vessel which, though not less of iron than before, still has no polarity, induced by her being built in the meridian line, or by the hammering of her rivets. This is to some extent valuable. But we cannot use the reflectors for compasses at twenty feet distance, I am afraid when Mr. Hopkins takes his place at the wheel of the ship and tries to look at a compass even ten feet off, during a fog or drizzle, he will find it so utterly impossible that he will be glad to go back to the old binnacle, and recognising the difference between it and the standard, steer his course as correctly as if his helmsman were looking at the standard. For it must be recollected that the helmsman is not the governor of the ship. The officer who gives him his course takes that course from, and sees that it is kept by the standard compass. He is walking by that every half-hour, and every minute of the half-hour, and he sees it, and if at any time the course is varied from that, he corrects the helmsman. But the helmsman knows no more of the true course of the ship he is steering than he knows where she is going. To arrive at a just conclusion of the value of Mr. Hopkins' general theory, I think we ought to take into consideration that the earth is a great magnet itself, produced by thermo-electricity. The Abbè Secchi at Rome, by making a globe, and passing a current round it in the

equatorial line, was able to produce, at the north and south poles, brushes of electricity, corresponding with the aurora borealis and australis; and was also able to produce a variation of the compass on a globe of paste-board. He was able to produce the lines of variation by means of this electrical current circulating in a copper wire round the equatorial line. Now, although we may find, as we do find, that there are very great deviations of the variation, so to speak; that, in fact, in 1662, the variation was discovered, first, not to be constant, and in 1663 it was nothing at all; it has gone on to 22, as we know, and it is now going back again; all this shows us that it is subject to some laws which we have not yet succeeded in ascertaining. If we once get into the proof of the theory that the earth is an electro-magnet, made a magnet by thermo-electricity, and depending for that thermal heat on the sun, we shall then see that the same causes which may be at work to change the character of our seasons, may also be at work to change the states of the variation. It is, perhaps, going too far into theory, but one of the most beautiful experiments of late years that has been tried is that of Professor Thomson, who, by the use of the ordinary poker, demonstrates the induction of the earth. He takes the poker which he finds magnetised, as Mr. Hopkins has shown you, by its position in a meridian line, or indeed in almost any line, if it be constant for a long time in that position. On taking the knob of the poker he finds it to be a south pole, on raising the poker he finds the other end is a north pole, the poking end. He has nothing to do but to invert the poker, and immediately that which was before a south pole gives north, and that which was before a north pole gives south, without any blow, without any change whatever. The induction of the earth, the great magnet, has sufficed to change the polarity of a feeble polarised body.

The Rev. Walter Mitchell: More than twenty years ago I saw that experimentally shown by Marsh, who was a well-known investigator of the laws of electricity. But to succeed in your experiment you must hold your poker in the magnetic meridian. It is a very old experiment. You must not only hold your poker north and south, but you must also hold it in the dip.

Captain Selwyn: I have myself used it without any attention to the dip, and I have found perfect success when the magnet on which I operated was a sufficiently light and delicate one. I have no doubt any of these little magnets on the table will show it at once. However, that may be, perhaps thirty years ago we did not reason quite so much on the theory of induction as we do now; nor did we understand the subject so well as we do now. It is an advance in that sense, inasmuch as it shows that the passage over the field of a magnet may operate a change which you were not prepared for at all; that if you have magnetism in your ship that may be another cause of error, and that it is desirable to get rid of even one out of many sources of error. It is a very ingenious plan, for getting rid of what has been objected to in iron ships laid down in certain meridians. There is a simple method which I had the honour of proposing at the Institution of Naval Architects, of correcting compasses at sea, without resorting to any other device. Whether Barlow's plates be used, or Gisborne's circulating currents be used, in either of these two cases you produce what we know as sluggishness of the compass; and wherever you cause a superior attraction to that of the earth to be felt, it is evident you cannot avoid such a condition. Without doing that at all I propose to pursue still further the question of raising the compass out of the magnetic field of the ship. I do not think any naval officer present will think it a very great difficulty to have a compass elevated as high as the truck of the vessel, which may be consulted once in a watch, by sending a man up who will hail the deck, and will tell you what the error by your standard compass will be. It is not a very difficult thing to do, and it may serve to satisfy men who are under difficulty with regard to their observation at the moment, and who also have some little distrust of the action of their compass although compensated by magnets. The other experiment which I may mention now, as it may have some interest for my brother Officers—I had the pleasure of showing at the meeting of the British Association at Birmingham, but I have not shown it here hitherto—is one which I believe is new in magnetism. It is that a magnetic bar of steel may be made to point equally well east and west as north and south. It only requires that you should

take a magnetic bar of hardened steel, and take out the temper at any portion of it at which you desire that the magnet—speaking of it as a magnet and not as a bar of steel—should be separated. A different molecular arrangement consequent on taking out the temper, seems to give you the power of placing the two north poles at the two ends, or the two south poles. You will then find that the opposite poles are arranged together, either in the centre or at the point where you have taken the temper out. And if you arrange it with either two north poles or two south poles it will then point east and west instead of north and south, a mere composition of forces. It is another peculiarity which may turn out to have its value; that although the ordinary magnetic bar will always be deflected by a galvanic current, by a magnetic power passing through it, this bar will, on the contrary, be retained strongly under the wire through which the current circulates. I think this will be found to have its value in the construction of magnetic instruments, and, possibly, in electrical investigations.

THOMAS GRAY, Esq., Board of Trade: I came here this evening expecting to hear a very elaborate and clever paper on the deviation of compasses in iron ships. Then I came here, not expecting to hear what I have done, that the element of political economy should be introduced into the discussion. Admiral Ommanney has been kind enough to say that the Board of Trade ought to interfere as regards the deviation of the compass in iron ships; and one or two other gentlemen have mildly and timidly, I may say, expressed the same opinion. Now, Mr. Chairman, I will take issue with Admiral Ommanney on that point, and on that point alone. I do not profess to understand terrestrial magnetism, and between ourselves I believe there are very few people who do. You have one of these wonderful things to-night. Mr. Hopkins has assured us that there is not a magnetic north pole. Sir Edward Belcher, says there is a magnetic pole. The lecturer says there is not, that it is a mere belt. This being the case how is it possible that a mere looker-on like myself should venture into these intricacies and troublesome facts, or rather conjectures. We know for a long time the Compass Department of the Admiralty have absolutely refused to correct their compasses by magnets. They have gone on a very good plan as far as it went, and as far as the requirements of a conservative body can go; but when we come to a body like the mercantile marine we want something beyond this. We are not to keep our ships in dock while the Admiralty and Professor Airy find out as to who is right or who is wrong. Professor Airy says to the Admiralty that the whole energies of the scientific world, magnetically speaking, should be devoted to the one object of correcting the compass by magnets, and making those corrections rigorously correct and easy of application. The Admiralty say, "We don't want that; we will not correct our standard compass by magnets. We will, perhaps, correct our steering compass." Now, here, we have a third person coming here and proposing to avoid the correction of errors altogether, by applying an electric current and taking the polarity out of a ship, and so keeping the steering-compass accurate. Now, I ask Admiral Ommanney, how can the Board of Trade decide when you have these three different plans advocated? Now, if such a measure as the Royal Society would propose were adopted, we should want to have a compass department and superintending officers at the out-ports. We should not only have to examine the compasses, but we should have to examine the men who examine the compasses; we should not only have to examine the build of the ships to see that they were right, we should have absolutely to see how the ships were built, with a view to take the compasses. After all that, it would be like the sand in the agate cup referred to, the whole would go to ruin. And yet there are people who advocate Government interference. I have an extract here from a very clever work, *Spencer* on *Over-Legislation*. He says:—

The CHAIRMAN: You are travelling from the subject, but go on.

Mr. GRAY: I place myself in your hands.

The CHAIRMAN: Go on.

Mr. GRAY: My extract is to the point. Here is Admiral Ommanney whom we all respect. We know him as an authority both in naval matters and scientific details; he is advocating the interference of the Board of Trade. Spencer says:—

"There is a great want of this practical humility in our political conduct. Though

we have less self-confidence than our ancestors, who did not hesitate to organize in law their judgments on all subjects whatever, we have yet far too much. Though we have ceased to assume the infallibility of our theological beliefs and so ceased to enact them, we have not ceased to enact hosts of other beliefs of an equally doubtful kind. Though we no longer presume to coerce men for their spiritual good, we still think ourselves called upon to coerce them for their material good—not seeing that one is as useless and as unwarrantable as the other. Innumerable failures seem so far powerless to teach this * * * * Take up a daily paper * * * * Here is a vehement condemnation of the police for stupidly allowing sight-seers to crush each other to death; you look for the corollary that official regulation is not to be trusted, when instead, apropos of a shipwreck, you read an urgent demand for Government inspectors to see that ships always have their boats ready for launching. Thus, while every day chronicles a failure, there every day reappears the belief that it needs but an Act of Parliament and a staff of officers, to effect any end desired.

"Nowhere is the perennial faith of mankind better seen. Ever since society existed, disappointment has been preaching 'Put not your trust in legislation; and yet the trust in legislation seems scarcely diminished.'"

Admiral OMMANNEY: I am very happy to have been the humble instrument of elucidating these amusing observations of the gentleman who has just sat down. I came here in no party spirit. I believe there is nobody here who can say the Royal Society is a Government body. I merely say as a humble individual, having studied the Admiralty Instructions, and having heard what the lecturer has said to-night, I only put more faith in those observations which have been drawn up by the Admiralty in preference to any other mode for correcting compass errors.

Rear-Admiral Sir FREDERICK NICOLSON, Bart., C.B.: I want to ask one question. We have been told to-night by Captain Fishbourne that this is eminently a practical subject.

Captain FISHBOURNE: I said the subject had been treated in an eminently practical way.

Sir FREDERICK NICOLSON: Very well; the subject has been treated in an em nently practical way. In the abstract of Mr. Hopkins' papers I find that ther is one statement which appears to me the most important, that is, Mr. Hopkin says he is prepared to destroy the polarity of any given ship in ten minute The only question I wish to ask, because the gist of the paper lies in that assertion is whether Mr. Hopkins has performed that operation upon any ship?

Mr. HOPKINS: No, not in any ship as yet; but I have made experiments on long bars and plates of iron, and I am quite satisfied that I can produce the same results on the iron plates of a ship. In reply to the observations which have been made I will not detain you long, because I do not think the remarks made require lengthy replies. First, with regard to Sir Edward Belcher's remarks, he said that I stated that there was no magnetic pole. I did not state that there was no magnetic pole; on the contrary, I have endeavoured to explain that *the entire areas bounded by the antarctic, and the arctic circles, are the great magnetic poles of the earth*, towards which all the magnetic meridians converge. I do not mean to say for one moment but what a dipping needle at the north latitude of 70° approached nearly 90°, observed by Sir James Ross, and probably over a great number of square miles in that region; but I have seen dipping needles approaching 90° near the Equator. There are many places in the islands of Scotland, also in Norway, Sweden, and Russia, where the dipping needle will not only approach 90°, but remain at 90°. Therefore I repeat that the dip of the dipping needle does not necessarily depend on the action of the terrestrial pole, but on local attraction. Besides, neither experiments, analogy, nor observations on the magnetic meridians support the notion of the magnetic pole being merely a mathematical point near Boothia Gulf. We have only to prolong the observed magnetic meridians to the circle of 70° of latitude to show the fallacy of the Boothian pole. We must be guided by the *meridians* of the needles to determine the position of the active polar areas. Go to Norway; go to Sweden; where do the needles point? Do they point to Boothian Felix? No; they do not. They point towards the Arctic region, and not to any special *point*. With regard to the

other point that Sir Edward stated with reference to the compass, I do not believe there is a possibility for the compass to point correctly unless it be left entirely under the control of the great terrestrial force: any interference, whether by magnets or electric appliances can only increase the confusion and danger, and therefore the compass should not be tampered with, but left to act freely and under the sole influence of terrestrial magnetism. With regard to what Captain Selwyn stated about the steering compass. He said, "Never mind that; I believe you do not care much for the steering compass, you go by the standard compass." Well, there is now always a difference between the standard and the steering compasses. We know that in iron ships that difference constantly varies. You do not know what the variation is that is constantly going on. Were you certain of the exact amount of variation it would be like the watch and chronometer spoken of by Captain Selwyn; but you cannot compare the case of your watch and chronometer with those of the standard and steering compasses when you have an iron vessel, and where you have a perpetual change going on in the action of the polarity of the iron vessel. With regard to the reflector, I see Captain Selwyn apprehends difficulty. I see none, and the appliance is already appreciated by several experienced captains. I do not think there would be much difficulty in seeing a compass with a good strong light with a 12-inch card at a distance of even 30 feet. However, I leave that to others. There is one thing Sir Edward Belcher mentioned with regard to the needles. I am perfectly familiar with all the needles they use in high latitudes. They are utterly worthless in *directive* power. As to the dipping needles they have no directive power whatever, and, as justly observed by Captain Fishbourne, have no lateral directive power at all, and cannot therefore serve as guides to determine questions connected with *meridian lines*. The *curved* magnetic needle will act where neither the straight nor the dipping needles can be rendered serviceable in high latitudes. It only remains for me, in conclusion, to thank you for the patience and kindness with which you have listened to the observations I have made.

The CHAIRMAN: I am sure there will be but one opinion among you as to a vote of thanks to Mr. Hopkins for the very interesting paper he has read. He has brought forward some of the old ideas relating to magnetism, which many here were not acquainted with, and he has given us some new ideas. I must say that his idea with respect to the bent needle is one which I think is deserving of a trial. I must also say I should like to see that dissipation of the polarity of a ship tried, although I am afraid that the soft iron of the ship would become magnetised by some other extraneous cause at present unknown. I really believe this, although we are very thankful to him for what he has told us, that we shall still find it positively necessary to have recourse to observation. I hope what you have heard to-night will strengthen your confidence in the compass as a means of steering. There is another remark about the pole. As I have passed within 70 miles of it, and the dip was 89° 47′, I must say that I can only look upon the pole as capable of being defined, not perhaps exactly as a point, but very nearly as a point, because as I passed up I changed from 89° 47″ north dip to 89° 46″ south dip. With respect to the deviation of the compass, it has been an old thing with us who have been in high latitudes. We know perfectly well that we suffer the same inconvenience which is experienced now in iron ships. In Behring's Straits, in going about there, the deviation of the ship amounted to six points of the compass; and I can say, which I have no doubt Captain Maguire will corroborate me in, that we should have had the greatest difficulty in the world to take our ships up into the position we did, if it was not for the admirable charts of Admiral Bechey, and in which expedition Sir Edward Belcher served. There is only one other point. I will say that I have listened to this paper with a great deal of gratification and pleasure, because during the course of my service in the Arctic regions, it so happened that for two years I was not able to use a compass at all; therefore, I am able to appreciate anything that will increase the value of it.

LECTURE.

Friday, February 2nd, 1866.

CAPTAIN E. GARDINER FISHBOURNE, R.N., C.B., in the Chair.

NAVAL ARCHITECTURE, AS AFFECTED BY THE LAWS GOVERNING THE TRANSITION OF CURVES.

By Commander B. SHARPE, R.N.

THERE are perhaps few subjects more replete with difficulties, and more requiring patient investigation than those which relate to the motions of bodies floating in fluids, the laws governing these motions never having been practically settled, although, from the days of Sir Isaac Newton to the present time, the attention of the scientific world has been engaged in their investigation: thus the action of water on the movements of a floating body still remains a disputed question among men of the highest attainments; but is not surprising when we consider the numberless forms which bodies floating in water are capable of assuming.

In the solution of this abstruse question, my recent discovery of the laws which govern the transition into other and dissimilar shapes, of lines of the second and higher orders when bounding the surfaces of solids, will probably afford material aid: for the velocity of bodies floating in water, being principally dependent on the external forms of the bodies themselves, the laws under which the bounding curves or describing lines of a floating body are obtained, must necessarily have a direct relation to the laws by which the movements of the body itself are governed: there cannot therefore be a question but that a law which, by controling the transition, will fix with precision the exact shape of the sectional curves for supplying the most favourable lines for each particular form of vessel, will prove of the highest value to naval architecture.

Among the more immediate difficulties which this discovery will remove, is the present uncertainty which arises from the absence of any reliable rules by which a naval architect can produce with any satisfaction to himself, the lines of least resistance for the particular form of vessel he desires to build; for at present he can only produce

approximately with his pencil, and not absolutely in a progressive order of increase or diminution, the successive curves of a vessel's transverse sections, so that during their transition from the principal sections, the intermediate curves may retain, under a *four-fold* influence, a similarity of feature in a gradually varying degree, until all distinctive character become finally merged in the plane of the stem as in the fore-body, or until, by the same gradual and imperceptible steps (after having lost the type of the sectional curves from whence they more immediately originated), they again become expanded to suit the altered shape of the quarter in the after-body.

Certain rules derived from the conic sections which, even for the express object of their author (as I will presently show) are incapable of universal application, were originated by Chapman, the Swedish architect, and in the absence of any better rules have since been commonly used by naval architects; but these rules are merely for supplying a consecutive series of *areas* for the different sections, and are quite incapable of producing the actual form of the vessel, as the curves which bound the sections cannot, by any possibility, be produced from the areas which the sections themselves are intended to contain. Curves, rectangles, and other dissimilar figures may equally bound the same areas; and beyond the supposition that a good vessel should possess the sectional areas to be obtained under Chapman's rule, this rule is of no avail in ship-building; so that in fact there are no practical means at present available for producing the sectional curves, in a thoroughly satisfactory manner.

The absence of any law governing the transition of these curves, adds also very considerably to the labour of calculating the elements in a vessel's construction; but if the bounding curves of a vessel's form, by a graduated progression under a law of transition, bore a fixed relation to each other, the various elements would naturally follow in a similarly connected manner; and instead of the present tedious and uncertain calculations, the mathematical labours of a naval architect would be considerably abridged, and brought within the narrow compass of a comparatively few figures.

Before entering more fully into the subject, it may be desirable to take a short review of the different methods hitherto adopted in designing ships, and as affording a concise summary I will quote from a treatise by Mr. Creuze (a distinguished member of the late School of Naval Architecture), which was prepared by him for the "Encyclopædia Britannica."

The author first draws attention to certain mechanical methods of designing ships formerly practised by English and French builders, "considering them in the absence of more correct principles to be "necessary, whenever the projected vessel was too large to admit of "being conveniently put up by the aid of the eye alone; and conse-"quently that almost every merchant builder was in possession of "some such empirical system to enable him to form a design for a "ship."

Among these mechanical systems he describes a very old plan termed "whole moulding," which, as it is a method of constructing

the square body without the fore and after extremities of a vessel, we need not dwell upon. Mungo Murray's system by the sector and two French methods are also described.

"These," he continues to write, "are some of the most esteemed "mechanical methods of constructing the midship sections of ships, "and the fore and after bodies in relation to them. The inspection "of them already shows that there is no attempt to describe a form "which is proved to possess any property conducive to the good "qualities of a ship."

He then remarks on the use of the circle and the ellipse, and observes, "Little can be said in favour of either of the methods of "designing bodies which we have described, nor need anything be "urged against them: it will evidently be perceived that they are the "resources of persons who are called upon to give designs of ships, "and who, being ignorant of any correct data on which to form their "designs, are necessitated to adopt some such system of construction "that they may designate as their theory. In no case do we find that "those who have published systems such as the foregoing, attempt to "prove that ships built after these systems are in consequence good "ships; the utmost assumption appears to be, that by proceeding with "a drawing after the course laid down, the result will be the design "for the body of a ship. All such methods are to be deprecated, as "being mere empirical substitutes for knowledge, and because they "not only oppose a barrier to legitimate attempts towards improve-"ment, but they actually prevent the application of such knowledge "to the designing of ship's bodies, as may really be possessed."

"Mechanical methods of constructing designs for bodies followed, "no doubt, immediately upon the method of constructing them merely "by the aid of the eye, and they continue to be very generally used "in the merchant service, and may, no doubt, be reckoned among the "causes which have operated so injuriously to the interests of our "mercantile navy."

After this strong condemnation of the previous modes of construction, the author proceeds to describe the parabolic system of the Swedish architect Chapman, to which I have already alluded:—

"Chapman endeavoured to discover whether or not the areas of the "several transverse sections in well-constructed ships followed any "law; and if so, to find that law. For this purpose he calculated "the areas of the sections of several ships; and in order to make "the numbers more convenient, he divided these areas by the breadth "of the midship section, then at their respective stations on the "drawing; setting off from the water line distances equal to the "quotients, he traced a curve representing the areas. This curve he "called the curve of sections. He then endeavoured to find the "equation to the curve, or rather that of another curve which would "coincide with this for the greatest length; and he found, that if the "power and parameter of a parabola were so determined as to allow "that curve to pass through three given points of the curve of sec-"tions, the two curves would nearly coincide. In the fore-body the "three points were taken, one forward, one at the midship section,

" and one midway between. In the after-body, the points were simi-
" larly situated. In some ships the exponent to the curve was higher
" in the after-body than in the fore-body; in some it was the same
" for both. It was also found that there were ships in which the
" curve of sections almost exactly agreed with the parabola, and these
" ships invariably bore excellent characters. Chapman consequently
" concluded, that if the areas of the several sections of a ship were
" made to follow the law of the abscissæ of a parabola, a vessel
" possessing good sailing qualities might be formed, and the process
" of construction much simplified."

I have given the passage entire, as it describes the ruling principle of Chapman's method, a method which, overlooking the external form of the ship, merely attempts to supply by an imperfect coincidence a consecutive series of *areas* which shall follow the same law as the abscissæ of a parabola; the sectional curves are thus left entirely to the unaided eye of the architect, it being impossible (as I have already shown) to derive them from the areas they are intended to contain.

It is therefore evident that however the transverse sectional areas of a good ship may be found to coincide with the law which governs the abscissæ of a parabola, the transverse sectional areas of the very worst of ships may equally be included under the same law.

But Chapman's rule is, even for the express object of its designer, incapable of universal application, for, quoting from the same work, it is stated, that "If the body has a long straight of breadth, and sharpens
" quickly at the extremities, by deducting a part in midships from the
" comparison, the system may still be applied; or if, as is the case
" generally with English merchant-ships, there is a very great draught
" of water in proportion to the breadth, by deducting a part from the
" water-line downwards, this method may be applied to the remainder."

In the one case a part in midships, and in the other a part from the water-line downwards, has to be deducted before the rule can be applied!

This concludes Mr. Creuze's review of the parabolic system, as proposed by Chapman, a system which, besides being open to considerable error in itself, is incapable of giving a shape to the vessel's bottom.

One of Chapman's principal objects in endeavouring to find an approximate rule for the areas of his transverse sections, was to lessen the labour of his calculations, but with this object before him it seems singular that he should so completely have overlooked the fact (already alluded to) that a law ruling the transitions of the sectional curves, while providing for one of the most pressing wants in naval architecture, would have answered his purpose infinitely better by furnishing him with a series of areas having a direct relation to each other and to the form of his vessel, and, as a natural consequence, supplying the elements of construction in a connected series.

But Chapman's rule is on every ground imperfect, and cannot in any way be classed with those general laws under which a great science can properly be brought.

A work on naval architecture of considerable dimensions, has recently been published by Mr. Scott Russell, but the author's theory of hollow

lines has been so long before the public, and so many eminent men have so thoroughly tested it in practice, and have proved it to be wrong, that I need not advert to it further than will shortly appear in the general exposition of the direct action of water on convex and concave surfaces.

In resuming the more immediate subject of this paper, I should remark that although the newly-discovered laws will actually produce the intermediate curves of a vessel's form (the major part of the vessel in fact), they must not be confounded with the form itself, but must rather be regarded as constituting the only proper means for its eventual production, as a skilful architect, by a proper combination of the values of his principal curves, can, under these laws, produce every conceivable form of vessel, any peculiarities of structure being anticipated and provided for in the features of the more prominent curves; these curves will then by this means become blended with each other in a harmonious series during their gradual transition from section to section, until their final extinction at the stem, stern, and keel; there cannot therefore be the slightest grounds for fearing that the genius of the naval architect will be unduly fettered by being brought under certain fixed laws, which although necessary for the production of the vessel's form, are but subsidiary to the form itself.

I am not aware of any previous writer on naval architecture having ever alluded to the possible existence of any laws under which a series of intermediate sectional curves (so formed as to offer the smallest degree of resistance to the passing fluid) could be supplied as connecting links between the more prominent curves, and yet it is difficult to conceive how the existence of such necessary aids in shipbuilding could for so long a time have remained unsuspected, for it requires but little examination into the subject to perceive, that intermediate between the more prominent curves of a solid raised above a plane, there must of necessity be a connected series of other curves, which by gradual steps will alone enable the more prominent curves, in minutely balanced proportions, to terminate in some other curve or straight line, and that such a transition must be governed by precise laws.

What these laws are, and what is the form best fitted for the fastest vessel, are distinct subjects in themselves and beyond the purpose of the present lecture. With respect, however, to the best form for a vessel, I may incidentally remark that ships being required for different purposes, are built under different conditions of form and dimensions, as it is not the greatest absolute velocity, but the greatest attainable velocity, compatible with a perfect adaptation of all parts to the immediate end in view, which is required in a perfect vessel; a race-horse and cart-horse are very dissimilar, and yet may be equally perfect of their kind, and for the purposes for which they are exclusively adapted.

As it is always best when investigating such questions, to present them in their simplest aspect, I propose confining myself exclusively to the form of the vessel under the load water-line, that being the

part which more immediately comes in contact with the water, and on which therefore the velocity of the vessel will more immediately depend.

In a design for the bottom of a vessel there are two principal sections, the horizontal section at the load water-line, and the vertical transverse section at the greatest breadth (the midship section as it is more familiarly termed), which, possessing the widest dimensions in their respective directions, in a great measure give the character to the future vessel, the curves which bound these sections being at the will of the architect and usually unconnected with each other. I trust, however, at some future time to establish an intimate relation between these two curves.

We will now consider the fore-body, and, both sides of a vessel being alike, it will be sufficient to allude to one side only, which being bounded by the curve of the midship section A K B (Fig. 1, Plate v), the curve of the water-line C H A, the stem C N D, and the keel D B, the two latter lying in the same plane B D C E, and the two former having each one of their ends in contact with the plane at B and C, the other end of each being in conjunction and raised above that plane by the distance of the vessel's half-breadth A E, the whole of them together containing the starboard half of the fore-body below the water-line.

To simplify the description, we will suppose the water to be passing by a vessel anchored in a tide-way, it being the same (as far as the present purpose is concerned) as if the vessel were moving through the water; C H A being the curve of the water-line, and A K B the curve of the midship section (both arbitrary curves), we have now to fill the intermediate space between the stem and keel with such other curves or lines as will combine the features of these two curves with the straight lines of the stem and keel in a gradually varying proportion, and which will also allow the longitudinal sectional lines to be continued in the after-body at an angle of 90° with the plane of the greatest transverse section (the longitudinal curves are, strictly speaking, the only curves which can properly be considered in reference to the passing fluid, the transverse sectional curves being a mere builder's convenience and deducible from them by a purely mechanical process).

The operation of the laws of transition is not, however, confined solely to the longitudinal and transverse sectional curves; sections, for instance, may be taken at any angle with the diagonals of the solid we are considering, the curves of which would be equally derivable under these laws, and (beyond entailing rather more work) the results would in every way be the same.

Let us now, however, consider the direction the water will take between the stem and principal transverse section with the view of arriving at some of the features of a longitudinal section which shall present the smallest obstruction to the fluid.

The water being obliged in the space of the vessel's half length to deviate to the left to the extent of the vessel's half breadth, would naturally find a straight line the most direct course, but having at the same time to enter the after-body at an angle of 90° with the plane of the greatest transverse section, the connection between the stem

Fig. 1.

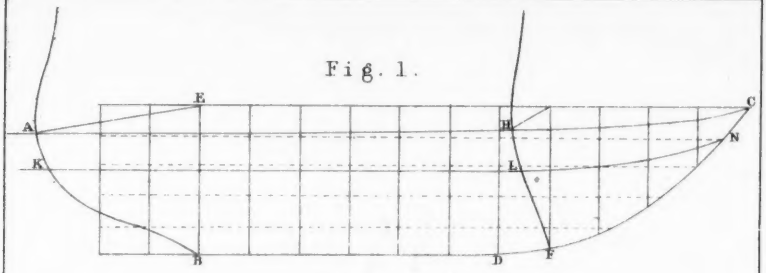
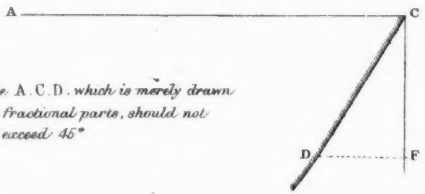


Fig. 2.



Note. *The angle A.C.D. which is merely drawn to avoid fractional parts, should not properly exceed 45°*

Fig. 3.

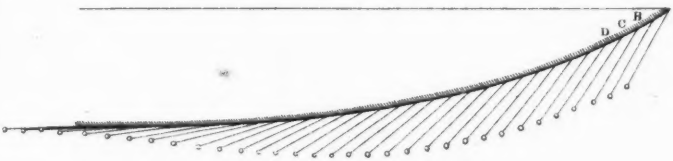


Fig. 4.

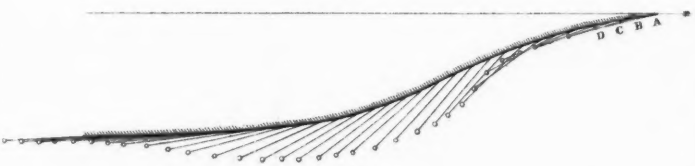
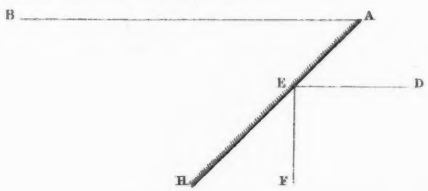


Fig. 5.



J. Jobbins

and this section must necessarily assume the form of a curve, some of the properties of which we will now examine.

Having commenced by assigning an arbitrary shape to the curve of the water-line A H C, that shape will naturally influence to a greater or less extent the shape of all the sectional curves parallel to it; the next curve, for instance, K L N must obviously bear some resemblance to it, or otherwise there would be an unconnected series of rounds and hollows; but this curve must also show its connection with the curve A K B, and with the keel B D, and stem D N C, in different degrees of intensity according to its proximity to each.

The curved shape of the water-line will thus become modified in K L N by three different influences, and if it be so with this curve, the same reasoning will apply with equal force, though in a different degree to the next, and so on, until the line of the keel B D has been reached; or, take the converse of this, and that the straight line of the keel has, under the same influences, become gradually expanded until the expansion has, step by step, at each longitudinal section, at last developed itself in the precise shape of the water-line; it will then be found that the contraction in the one case, and expansion in the other, have been proceeding by varying, but harmonious curves, under an exact law.

It will hence be evident, that with the two arbitrary curves of the water-line and midship section (and if the vessel is to possess any special peculiarity of form, either in excess of, or falling short of the lines of least resistance, such other section or sections passing through the exceptional part), we shall have certain fixed data, which point to an equally fixed series of intermediate curves for outlining a solid that shall offer the smallest degree of resistance to the passing fluid, which a solid possessing the particular arbitrary curves is capable of.

As regards the general connection of the longitudinal curves of the fore- with those of the after-body, there will be no difficulty, provided the curve of the water-line has been accurately formed, with a view to its prolongation in the latter body, as the curves consequent on it will, under the transitional laws, be continued in the after-body in an equally perfect manner.

We will now take the curve of the water-line, and other longitudinal curves, and observe how they are acted on by the fluid, and how an expansion or contraction of any part of these curves tends either to facilitate or retard the progress of the vessel (for many points of much interest and importance will arise from the examination), and to aid us we will divide the subject under certain prominent heads as, *first*, the course taken by the fluid along the vessel's bottom; *secondly*, the adhesion of the particles of fluid to the vessel; and *thirdly*, the action, inaction, and reaction of the water in connection with the vessel.

With respect to the movement of the fluid along the bottom, I am not aware that any previous writer has ever drawn attention to the singular fact (no less paradoxical than true), that, at whatever rate a vessel may be moving through the water, the fluid in immediate contact with her will pass along her bottom at varying, and generally at

far greater, rates of velocity than the vessel herself is actually moving over the ground, or in the case of a vessel anchored in a tide-way, than the tide or stream is actually running; a vessel moving at the rate of ten knots may, for instance, have some part of her bottom passed over at the rate of twenty, and whatever may be the speed of the vessel, the fluid will always pass along her bottom with an unequal velocity, which being alone due to the shape of the bottom, there will always, whatever the velocity of the vessel, be the same relative difference between the various streams of the passing fluid in immediate contact with the vessel, which I will endeavour to show.

(It is best to assume that curved lines are composed of a number of short, straight lines, which, while following the direction of the curve, form a connected series of angles with each other, and with some straight line common to them all; any portion of the curve may by this means be separately distinguished and described as possessing a particular angle.)

The line D C (Fig. 2) represents a portion of the water-line of a ship, which forms the angle D C A with the fore and aft line A C, the dotted line D F (showing the direction of the stream) being drawn parallel to A C, C F being at right angles with the two lines, and connecting them. Let C represent the vessel's stem, and C D be twice D F in length.

The ship being at anchor in a tide-way, if a particle of water strikes the stem at C, and is then diverted to the starboard side (the side shown in the figure), it will pass along the line C D in the same space of time that another particle, parallel to it, will occupy in moving from F to D, both particles being borne onwards in the general body of the stream, but the distance between C and D is twice that between F and D; the particles moving along the line C D must, therefore, in order to maintain their relative position in the stream with the other particles moving in the direction from F to D, move with twice the velocity required by these latter particles, and in a ten-knot tide the water will consequently pass from C to D at the rate of twenty knots, the difference between the two velocities being the same as the difference between the hypotheneuse and base of a right angle triangle, the base of which is drawn parallel with the stream or fore and aft line; as the longitudinal curves in receding from the stem approach the principal transverse section, they approach nearer and nearer to this line, so in like manner and to the same extent, will the difference in length between the hypotheneuse and base of the right angle triangle decrease until the curve coincides with a line parallel to a fore and aft line, when all difference will cease, the velocity of the particles of water in immediate contact with the vessel being then the same as that of the general stream.

It will be observed from this, that the velocity of the fluid moving along the longitudinal curves of a vessel's bottom, becomes increased or diminished as the curves depart from or approach a fore and aft line, by which we obtain an exact measure of one of the principal features in the action of the water on the vessel, and which furnishes us with valuable aid when tracing a vessel's lines.

To enable us to realise to some extent the great difference in the velocity of the various streams of moving water in immediate contact with the vessel, let us suppose ourselves on board a ship anchored in a tide-way, and having a transparent bottom of glass. We should then, on looking through the bottom, observe the strange spectacle of the particles of suspended matter rushing about in apparent confusion, here with an accelerated motion, there slowly progressing with the general body of the stream, but rarely, even with contiguous particles, at the same rate of velocity, and yet amid this seeming confusion, we might easily trace the onward progress of all the particles in obedience to a general law, and might perceive that the difference of velocity in the various streams arose entirely from an exercise of this law in preserving an equilibrium in the general progress, which the presence of a foreign body had tended to disturb.

As this relative difference in the velocities of the streams of water can be easily calculated at every part of the vessel's bottom, the naval architect will have at his command a valuable aid in forming his design.

That the adhesion or attraction of the particles of water to the vessel's bottom (the next point) will occasion a diminution of speed, is a recognised fact, but it is at the same time very questionable whether it has exercised any influence in shipbuilding; and beyond making the bottom as smooth as possible, and the occasional use of some external application (such as black lead), it does not appear that any other means have hitherto been adopted for counteracting the effects of friction, or when designing a vessel, that any strong necessity has ever been felt for keeping under the extent of frictional surface as constituting a very serious drawback to the vessel's speed. It is singular that the direct sacrifice of velocity caused by the adhesion of water should have been so generally overlooked, as the magnitude of the evil ought to have been sufficiently obvious from the well-known strong adhesion of water to any foreign body immersed in it. Even so smooth a surface as glass will cause the water to adhere to it, as the amount of water raised by a glass wheel placed perpendicularly with its lower half in the water and made to revolve rapidly, will testify the force of attraction, or the adhesion of the particles of water being momentarily greater than the force of gravity; so powerful indeed is the adhesion of water to a foreign surface immersed in it, that a web of cotton revolving round two rollers is commonly used in the east for raising water.

Some theorists, however, have so entirely overlooked the effects of friction, as to maintain that the longer the vessel, the greater will be the speed, the fallacy of which theory may be soon shewn by comparing a ship of 4,000 tons displacement (constructed in the usual manner) with a rope having only a transverse sectional area of an inch, but yet of such a length as will give the same total displacement of 4,000 tons, and we shall then have two bodies both occupying the same space in the water, the one nearly 4,000 miles in length, the other not so many inches; and it will be seen at a glance that the resistance caused by the adhesion of the water must in the former case be so great, that all

the steam power of England would, if the rope were sufficiently strong to bear the strain, be incapable of moving it, while in the latter the position of the ship might be easily changed by merely a few men hauling on a warp; a three-decked ship (as many of us are aware) has even been moved when in dock by a single man hauling on a rope yarn which has been fastened to her.

This comparison shews very clearly what will be the effect of water on an extended frictional surface, although under the favourable circumstances of a very small diameter; and therefore what will be the result when the length of a vessel is too great in proportion to the breadth (the displacement being in all cases the same).

The extent of the frictional surface of a vessel's bottom has therefore as positive a value in shipbuilding, as any of the other elements in a vessel's design.

We will now examine the different stages of the action, inaction, and reaction of the water when in contact with the vessel, the immediate question being the disposal of a certain quantity of water which has been displaced by the moving vessel.

(It is best in our present inquiry to assume that water is practically incompressible, that it occupies a definite amount of space, and when displaced by a foreign body that it will occupy the same extent of space elsewhere.)

The disposal of the displaced water under the slower movements of a vessel naturally comes first, but the question of shipbuilding being so little affected by it, it need not occupy us long: in light airs, when the vessel is just forging ahead, the movement of the displaced water may generally be observed in close proximity to the sides, giving the vessel the appearance of moving much faster through the water than her actual rate of progress; the necessity for occupying the space vacated by the vessel, causing the water which has been displaced at the bow to be attracted towards the stern.

We will now proceed with the higher rates of velocity, taking, *First*, the incidence of the water at the bow, with its accompanying reflection; *Secondly*, the subsequent pause of the fluid; and, *Thirdly*, the after reaction of the water, with the restoration of the equilibrium and pre-existing state of the fluid in the after-body.

There are here what may be viewed as three distinct stages in the action of the fluid, all of which in a properly proportioned vessel, should be confined within the limits of the vessel's length.

When the fluid first comes in contact with the bow, (the angles of incidence and reflection of a body striking a plane being equal, as may be observed when water is poured from a pump, or from some narrow-mouthed vessel on a flat surface inclined at an angle to the falling fluid), all the particles of water striking at the same angle will leave, or rather will strive to leave the bow at the same angle, and pass away in parallel lines (so far as the adjacent fluid will permit), without interfering with each other, and still less will these streams of displaced or reflected particles cause any obstruction to each other when the angle of the bow presents a convex surface to the stream, and becomes reduced as from B to C, C to D, and so on in succession, as shewn in

Fig. 3, as the deflected streams will then pass away in diverging lines, the space between each stream continually increasing, and thus affording an ampler space for the displaced fluid to become diffused; but if, on the other hand, the vessel's bow is formed with an increasing angle (or, in other words, has hollow or concave lines in it, as in Fig. 4), there will be an immediate clashing of the reflected streams, from each striving to cross the other in counter-currents, causing an accumulation in the vessel's path, and preventing the rapid departure of the displaced fluid, the water gravitating equally on all sides, and as much towards the vessel as away from her; (the tendency of all concave surfaces to form eddies when exposed to a running stream being a fact familiar to us all, and easy to be seen wherever indentations in the banks of rivers divert a portion of the passing current which then accumulates and revolves with a force proportioned to the strength of the stream and the character of the indentation); and so in like manner will the fluid accumulate and obstruct a vessel having hollow or concave lines in her bow, as represented by Fig. 4, where the current of water deflected from the plane A B is represented as crossed by the stream leaving C D, and so on, the water discharged from each plane in succession forming an obstruction to the fluid previously deflected, and a serious impediment to the progress of the vessel: this, as I have already shewn, will not happen with a convex form of bow, which thus possesses great advantages over the concave.

Although the convex form of bow is thus free from the serious drawbacks attendant on the concave, no part of it must ever be allowed to describe a greater angle than 45° with the fore and aft line, or the water reflected from it will be thrown in the vessel's path; but before quitting this part of the subject it may be desirable to show this by a diagram.

It will doubtless be admitted without dispute, that to avoid causing an obstruction, the water must be discharged within a right angle with the keel (right abeam in fact, or at any angle in a direction abaft the beam), and that if it be reflected before the beam it will be thrown in the path of the vessel; an angle of 90° with the keel is then the extreme limit at which the reflected streams of water can leave without being thrown in front of the vessel to be again and again reflected, until from an excess of accumulation, they escape by gravitation beyond the line of the extreme breadth.

We will now turn to Fig. 5. Let A B be the line of keel, B A H the angle formed by a portion of the bow H A with the keel, D E the direction taken by the water when approaching the bow, and E F (drawn at right angles with D E) the subsequent direction of the water after its contact with the bow.

As only an angle of 180° (or two right angles) can be contained on the straight line A H, and the angle D E F being a right angle, it follows that the angles D E A and F E H taken together must also contain 90°, and the angles of incidence and reflection being equal, each of these two angles must necessarily contain 45°, which is the case, and D F being drawn parallel to the line of keel A B, and the straight line A H cutting the two parallel lines D E and A B, and

making the alternate angles equal, the angle D E A must therefore be equal to the angle E A B, and consequently 45° (or the half of 90°) will be the greatest angle with a fore and aft line which any part of a vessel's bow should ever assume.

In this manner the fluid will be found to act when the velocity is not extreme, but with a more rapid movement the vessel will pass onwards before the fluid has had time to gravitate in any direction, the displaced water becoming raised like a ridge on either side of the vessel which it tends to support at a higher level; but increase the velocity still more, and the vessel will then have a tendency to skim on the surface of the water like an oyster-shell thrown from the hand of a boy, the resistance of the fluid momentarily overcoming the force of gravity (I am now of course alluding to velocities hitherto unattainable except with mere models).

We will now return to the ordinary circumstances of velocity when there is a sufficient time for the dispersion and reaction of the fluid.

It must be evident, as regards the displacement of the water, that whenever in a tide-way any particular spot in the stream arrives at the vessel's stem, the displacement of water by the vessel will commence at that spot, and will continue until the spot arrives at the greatest transverse section, when it will cease; the difference between the areas of the intermediate transverse sections successively passed by the particular spot marking the rate of the displacement at each section, and as the longitudinal curves almost blend with a fore and aft line for some distance before they approach the midship section, so will the difference between the sections become gradually smaller, and the displacement of the water gradually less as this section is approached, and the reflective forces called into action at the bow will then have time to subside before the lessening sections of the after-body cause a powerful reaction of the fluid in a contrary direction.

If a reaction in the after-body were not an absolute necessity, a straight line from the bow to the principal transverse section would supply the shortest line of approach to that section, but as the after-body has to be considered, there must be such a longitudinal extension of the vessel's form in amidships as will prevent any angle being formed, and as will suffice for the gradual extinction of one set of forces, and the equally gradual creation of another, time in fact for a reflux of the fluid; the central part of a vessel may hence be considered as a zone for separating the active from the re-active forces, and thus permitting the gradual transition of the one into the other, and this space is as imperatively demanded for the speed of the vessel as the bow that cleaves or the after-body that reunites the fluid. for should the vessel be too short, and without a sufficiency of length for the natural reflux of the water, there will be formed both at the centre and at the stern, the suctional hollow, or the tendency to form a vacuum, which nature seeks to obliterate by accompanying waves, the form and character of which, under the different circumstances of length, may be observed whenever a *gig* and a jolly-boat are towed astern of a vessel moving fast through the water.

There must therefore (as I have endeavoured to show) be such an addition to the vessel's length in amidships as will correspond with the time required for the reaction of the fluid, any length beyond this detracting from the speed.

These constitute some of the principal though not generally recognised grounds for determining the proper length of a vessel.

In the displacement of water, time is an all-essential feature, time for the fluid to quit, time for it to pause, and time for it to return, and this reminds me that I am approaching the limits of my time though not of my subject, of which we have scarcely entered the confines.

I have endeavoured in the course of my remarks to bring under your notice certain fundamental though hitherto neglected principles in naval architecture, but the whole subject requires a far closer examination than is possible in a single lecture, or indeed in several, for problems of the highest order are involved in the movements of bodies floating in fluids, which movements will never be satisfactorily settled by mere abstract theory; and without a practical knowledge they will ever remain a sealed book to the philsosopher.

The whole subject, moreover, is beset with anomalies sufficient to shake the confidence of even professional men, as for instance there are numbers of vessels in whose structure every established principle in naval architecture appears to have been outraged, and yet these vessels (under certain circumstances) are capable of a high velocity, this, however, may be easily accounted for, as the best vessel is but a compromise; the ship that attains a high velocity when running free will probably be deficient in some important essential when hauled on a wind where a lateral pressure has to be provided for, and this pressure cannot be thoroughly met, without the speed suffering when running off the wind; absolute perfection under all circumstances is unattainable, and even under the same general conditions cannot always be insured, as for instance if a vessel on a wind could always be kept on the one tack, the portion of her form required for support on the other might be altered, or perhaps altogether omitted with advantage to her speed; and, singularly enough, in support of this assertion, a case happened during the war with France, when a French privateer, from falling over on her side while building; had one of her sides so altered in shape that when subsequently tried she was found to possess remarkable speed on the one tack, while on the other she proved a complete failure.

There is one general remark I wish to make on the subject of comparisons between different vessels, viz., that in all cases the displacements of the competing vessels should be alike, or the results will be valueless; extreme length, number and weight of guns, extent of canvas carried, and other similar standards of comparison, have each at various times been adopted as a common basis for the competition of rival builders, but, as the sequel has proved, without any advantage to the science of naval architecture.

I have now endeavoured to shew the entire absence of any reliable rules for producing the actual form of the vessel; and I have tried to

prove (as I trust to your satisfaction) that between the chief outlines of a vessel's bottom, there must be an intermediate series of sectional curves as connecting outlines, which bear in graduated proportions the impress of the more prominent features, and which will alone supply the lines of least resistance that each particular form of vessel is capable of possessing, and that such curves do not admit of any arbitrary formation, but must be produced under the stringent provisions of an exact law. I have also shewn the advantages of a law of transition for other purposes, and have briefly outlined some of the principal points which attach as corollaries to the problems I have brought before you, and they embrace some of the most interesting and important questions relating to the motions of bodies floating in fluids, and which must necessarily form the basis, indeed the very essence of any system of naval architecture. The whole subject has been to me one of absorbing interest, and with a lengthened experience as a guide, I can feel a confidence in the conclusions I have arrived at, which no mere abstract theory could ever have imparted.

My desire throughout has been to trace the existence of positive laws, so as to convince you of their presence, feeling how futile has been, and ever will be, every attempt to build up a permanent system of naval architecture, unless such system be based on those immutable laws which pervade all nature, and which will as assuredly be found governing the motions of bodies in fluids as guiding the planets in their courses.

I have now in conclusion to thank my hearers for their kind attention to my remarks, and if I have been so fortunate as to present these nationally important questions in such a light as will tend to advance the science of naval architecture, I shall have the satisfaction of feeling that neither your time nor my labours have been bestowed in vain.

The CHAIRMAN: Captain Sharpe has been dealing with a confessedly difficult subject, and has very justly shewn that owing to the lines of ships not being drawn according to any definite law, all calculations, whether for contents or any other object, are but approximations, whether they be made on Chapman's system or that in use amongst the French. I cannot pretend to say that I have followed him in his idea as to the transition of curves, as he only mentioned, without indicating, the nature of his discovery. I may say, however, as to Captain Sharpe's view in reference to the convex bow, that Mr. Michael Scott, who professes to have discovered the power of least resistance, and to have satisfied the Admiralty authorities as to the correctness of his calculations, differs entirely from his view, and Mr. Scott's view has been confirmed by the success of a vessel built on his principle, that has answered all his anticipations. We shall hope he will take up the gauntlet thrown down by Captain Sharpe. Under any circumstances you will doubtless allow me to offer your unanimous thanks to Captain Sharpe for his contribution towards the eliciting of truth on this important subject.

Evening Meeting.

Monday, February 5th, 1866.

CAPTAIN SIR JOHN C. D. HAY, Bart., R.N., F.R.S., in the Chair.

NAMES of MEMBERS who joined the Institution between the 29th January and the 5th February.

ANNUAL.

Wilmot, Fras., Lieut. 33rd Regt. 1*l.*
Boileau, W. S., Capt. R.E. 1*l.*
Keith, W., Capt. R.E. 1*l.*
Duncan, P., Capt. West Cork Art. Mil.
Manguy, F. B., Capt. R.E. 1*l.*
Marten, F. Capt. R.N. 1*l.*

GUNPOWDER—GALE'S PLAN FOR RENDERING IT NON-EXPLOSIVE AND RE-EXPLOSIVE AT PLEASURE.

By Mr. W. SAUNDERS.

MR. SAUNDERS: In acceding to the request of the Committee of this Institution to read a paper on "Gunpowder—Gale's plan for "rendering it non-explosive and re-explosive at leisure," I have not overlooked the fact that I shall be tempted to address myself to certain subjects on which many persons present have far more knowledge and experience that I can pretend to possess. I shall, however, endeavour to confine my observations to such portions of the subject as can be understood equally well by civilians and military men. I think I can see quite sufficient room for the useful and almost universal application of Mr. Gale's invention without insisting upon its use on board ship, or in military trains, or other situations about which civilians remain, and are likely to remain, in happy ignorance. It will be for military and naval officers to determine how far the principle can be applied in actual warfare. On this part of the subject I urge nothing, and yield nothing. I shall simply avoid darkening counsel by words without knowledge.

I cannot but respect and admire the feeling which I have frequently heard expressed by officers that a large amount of safety would be dearly purchased at the sacrifice of a small amount of convenience. The sentiment of the soldier who declared that shirt sleeves were the armour which he liked to fight in seems to be universally re-echoed, and freedom from restraint, not freedom from danger, appears to be always demanded by soldiers in time of action. How far freedom from danger in the use of gunpowder may be made actually conducive to freedom of action I must leave for those who are experienced in warfare to determine. Fortunately, the days of peace are far more numerous than the days of war, and if gunpowder can be rendered harmless during the time that we are not fighting, an important object will be gained.

No one will be disappointed this evening if I do not go into the history of the manufacture of gunpowder. We are all acquainted with the material; we know its value, and we know its power. Our attention to-night will be directed simply to this one point—can we make it a more useful servant and a less dangerous master? It is clear that under the present state of things gunpowder and colonies do and will occasionally explode, and we may well consider whether we can lessen the evils which history has shown to be of constant recurrence.

It is a remarkable circumstance that many of our most distinguished men owe the development of their character to the energy with which they have devoted themselves to the mitigation of evils and sufferings to which they were not themselves personally exposed. About 100 years ago a poor but intelligent lad in the extreme west of Cornwall read in a newspaper an account of an explosion of fire damp-which took place in South Wales. His mind was so much distressed by the sufferings occasioned by this calamity that he determined to give himself no rest until he had discovered a remedy for the danger. He was then poor, and had received but little education, still he had sense enough to perceive that the study of chemistry might lead to the evidently-desired discovery, and he pursued the study of that science until his efforts were crowned with success, and Davy's safety lamp became known throughout the world.

In a somewhat similar manner it was the explosion of a siege train at Inkermann in the year 1855 that turned Mr. Gale's attention to the evils which arise from explosions of gunpowder, and which ultimately led to the discovery of a simple and effective process by which, under ordinary circumstances, they can be altogether prevented.

It is a singular circumstance that the very same means are employed by Mr. Gale to prevent explosions of gunpowder, as were employed by Sir Humphrey Davy to avoid explosions of fire damp. In each case the protection depends upon the suitable use of gauze wire, and in each case protection is obtained by dividing the explosive material and preventing it from burning or exploding in a mass.

Without going very deeply into the atomic theory we may safely assume that practically there is nothing so small, but that there may be something smaller.

Mr. Gale has availed himself of this fact. There are no grains of gunpowder so small that a smaller grain may not be found which can be easily mixed with and readily separated from the grains of gunpowder. The more thoroughly Mr. Gale investigated this principle the more applicable did he find it to be, and it is now well known that the mixture of a fine non-explosive non-combustible powder with gunpowder will not only prevent it from exploding, but will actually prevent it from burning. It has, moreover, been ascertained that when properly prepared this protecting powder can be instantaneously and completely separated from the gunpowder which is thus restored to its original explosive condition.

When Mr. Gale did me the honour to consult me on the subject I had the good fortune immediately to perceive its great importance and utility, and since that time Mr. Gale and I have been jointly devoting our energies to the development of the principle; I, therefore, stand before you as an interested person, whose statements ought to be received with all due caution. I have, however, yet to learn that a person who is interested is necessarily prejudiced. Who can have more occasion than I have to look carefully on all sides of this question? Any reasonable man entering upon any undertaking naturally looks most carefully at the obstacles and difficulties he will have to encounter, and certainly I would not lend a hand to this or any other work unless I felt confident that well directed efforts would ensure its success, which, if the theory is inherently bad, can never be obtained. We have now the assistance of an experienced Board of Directors, every one of whom has entered upon the undertaking after a careful consideration of its actual merits.

We have certainly no reason to complain of the manner in which the invention has been received either by the Government or the public. Our first experiments were made at Plymouth before Viscount Templetown, Commander of the Western District, Sir Charles Fremantle, and other distinguished officers, who expressed their approval of the invention in a most decided manner. We afterwards attended at the War Office and the Admiralty. The Duke of Somerset and the Earl de Grey witnessed the experiments with much interest, and the Minister of War immediately referred the matter to the Ordnance Committee. The Ordnance Committee gave us an early audience, and have instituted a series of experiments, upon which at some future time a report will probably appear. As they have not informed us of any difficulties in the application of the invention, we may fairly assume that no difficulties have occurred which they have been unable to overcome. His Grace the Duke of Cambridge manifested a very lively interest in the experiments, and appeared to be especially struck with the advantage which must result from the protecting powder preserving the gunpowder from damp.

With regard to measures of a more practical nature, but little time has been lost. It is only a few months since the invention was made known, and already a Company has been formed for carrying it out, and measures have been adopted for preparing the protecting powder, and supplying the public with protected gunpowder.

This rapid progress has been owing not so much to any special energy on the part of individuals as to the eminently practical and advantageous character of the invention. It is rarely that the employment of one simple means produces such striking and manifold results. The chief difficulties to be encountered in the carriage and storage of gunpowder are its liability to danger, damp, and dust. These three words describe the three evils by which the carriage and storage of gunpowder are surrounded. Mr. Gale's process meets them all in one operation. It completely annihilates danger by making the gunpowder not only inexplosive but actually incombustible.

As a proof of this the President will perhaps allow me to put a fuze into a bowl of protected gunpowder. [This was done, and the result was that a few sparks only were visible. Some of the protected powder was then separated, and a small quantity of neat gunpowder exploded on the top of the protected powder which remained in the bowl. The neat powder exploded with the usual smartness, and the protected powder was undisturbed.]

The efforts which are constantly made to keep our powder dry are constantly frustrated by the circumstance that the atmosphere penetrates the contents of a barrel and finds its way to every grain, and the powder attracting the moisture of the air, quickly becomes unfit for use. This action of the atmosphere is prevented by the fineness of the protecting powder which entirely excludes the air and keeps the powder in its original condition. If a barrel or a bag of protected gunpowder fall into water, it would not be damaged beyond a mere outside coating.

If gunpowder is packed close in the barrels in which it is placed the grains will adhere to each other, and there is a danger of the whole becoming a solid mass. To obviate this danger, the barrels are only partially filled, and thus when moved, the powder is shaken and the grains are kept from adhering to each other. But this shifting of the gunpowder involves another difficulty. The attrition of the grains causes particles to rub off and the powder is thus made dusty, and rendered unfit for use, for if gunpowder was used in this state, the results would be uncertain, and no kind of practice could be relied upon. When gunpowder is mixed with the protecting material, it can be tightly packed, and thus all friction in the barrel is avoided, and no dust is made.

It is desirable to form some estimate of the value of this protection and to ascertain as far as possible what is the extent of the evils connected with the present system of treating gunpowder, and which would be obviated by Mr. Gale's process. What, for instance, is the extent of the *danger* to which we are now exposed by unprotected gunpowder. We know the number of lives that are lost in various dangerous occupations. We know that a certain number of persons are killed annually in the streets of London. We know that so many lives are lost annually from shipwreck—so many in coal-mining and other dangerous occupations. It will perhaps be surprising to some persons to learn that during the last ten years, three times the number of lives have been lost by explosions of gunpowder that were lost in

that deplorable accident, which has cast a gloom over the whole country, the foundering of the "London." It appears that the accidents from explosions of gunpowder have been regarded as so inevitable that no pains have been taken even to record them. But from a partial inspection of the columns of the public journals during the last ten years, we find that during that period, the loss of no less than seven hundred persons has been recorded.

It may be interesting to trace some of the most remarkable of these accidents.

The explosion of the siege train at Inkermann was the occasion which called Mr. Gale's particular attention to the desirability of protecting gunpowder:—

"It took place in what was technically known as the park, an enclosure about a hundred yards long by fifty deep, and surrounded by a stone wall which separated it on one side from the English siege train. It contained amongst other immense quantities of warlike material, 100,000 lbs. of gunpowder, and was extensively covered with the huts of the officers' quarters. Some French artillerymen were engaged in shifting powder from case to case, and every care was, as usual, taken to prevent accidents. As one of the soldiers was pouring the powder out of a case, he perceived a fragment of shell gliding out of it into the funnel, and, not wishing to let it get into the other case, he jerked the funnel on one side. The piece of shell at once fell upon the stones, which were covered with loose powder, and this is supposed to have struck fire in its fall, for the explosion took place at once. The French had six officers killed and thirteen wounded; sixty-five of their men, mostly of the artillery corps, were killed, and 170 were wounded. The English loss was one officer and twenty non-commissioned officers and men killed, and four officers and 112 non-commissioned officers and men wounded. In the Land Transport Corps of the English Light Division, fourteen horses were killed and seventeen were wounded. The destruction in money value of articles appertaining to the siege train was enormous."

The foregoing is an illustration of the effects of an explosion in time of war. We will now give an illustration of an explosion in time of peace, which took place in the town of Salonica in Turkey:—

"About nine o'clock in the evening of Friday the 11th of July, 1856, a great fire broke out in a Turkish inn, in the Frank quarter of the town, which speedily extended over the houses in the vicinity. The fire was after a time got under, and the people, who had gathered in the streets and thronged the hippodrome, were preparing to retire, when all of a sudden a fearful explosion shook the city from the Seven Towers to the Vardar Gate. It appeared that one John Schlizzi had secreted in his house about 200 barrels of contraband gunpowder, and this exploding destroyed two-thirds of the buildings in the town, shook down the boundary walls, and caused the conflagration, which had been so nearly extinguished, to extend to the newly-built warehouses without the city gates. More than a hundred lives were lost, and the destruction of property represented

"a value of a hundred millions of piastres, or more than a million "stirling."

The next disaster of any importance was that which caused a sacrifice of twenty-five lives in the Federal fortress of Mayence. "About "three o'clock on the afternoon of the 18th of November, 1857, while the "soldiers were at drill in the citadel, the magazine blew up with a "shock that was felt at Wiesbaden, on the other side of the Rhine. "Two Austrian and nine Prussian soldiers, with fourteen civilians "were killed, while seventy-four Prussian and ninety-four Austrian "soldiers, with 300 civilians, were more or less dangerously wounded. "The loss of property amounted to more than a million florins "(£100,000).

"By far the most destructive explosion which has visited the British "Isles for a long number of years was that which characterised the "blowing up of the magazines at Erith, on the morning of Saturday, "the 1st of October, 1864. Although the scene of the catastrophe "was fifteen miles from Charing Cross, the shock was heard and felt "throughout the Metropolis, and in many cases it was experienced "forty or fifty miles from Erith.

"At Erith and at Belvedere, where the shock was most felt, the "feeling produced was described as having been awful, beyond de-"scription. An immense pillar of smoke rose from the plain, ascend-"ing high in the air thick, black, and palpable, with a top like unto "the huge spreading foliage of a monster tree. A quarter of an hour "elapsed before it died away. Of the magazines, not a single stone "remained one upon another, the very foundations were torn up, and "the sites marked by vast fissures and chasms in the earth, enormous "lumps of which had been scooped out and hurled about the adjacent "fields, and an enormous rent was made in the embankment itself, "exposing many miles of the country to the perils of an inundation. "The chasm was a hundred yards in width, but fortunately it was "dead low water at the time, and during the few hours which were "available, a host of sappers and miners from Woolwich arsenal, "assisted by a number of navvies, succeeded in repairing the breach "with sufficient strength to resist the force of the advancing tide. "The cause of the calamity is said to have been 'beyond even the "reach of conjecture.' The damage done at Woolwich and at Erith "was enormous, and altogether represented a sum of £200,000. Ten "lives were lost through this terrible calamity."

The quantity of gunpowder exploded was 104,000 lbs.

The unfortunate sufferers by the explosion at Erith find that they have no remedy against the owners of the magazines which caused the destruction of their property. Fortunately most of the land in that neighbourhood belongs to wealthy persons who can bear a loss without personal suffering, but there are some very sad instances where poor persons with a little property have suffered severely from its destruction. The losses to the wealthy proprietors has been prodigious. On one estate the glazier's bill alone amounted to over £2,000. One large source of loss is the depreciation of the value of building sites in the neighbourhood, and it may be imagined that few

persons would like to build within sight of a gunpowder magazine after the experience of the Erith catastrophe.

We next come to an explosion at sea:—

"The Bombay was a screw steam-vessel, carrying 67 guns, and "with a tonnage of 2,782. On the morning of the 14th December, "1864, the Bombay left the anchorage at Monte Video under sail. "She had proceeded only a very few miles out to sea, and the men "had only placed one target for practice, when fire was reported to "have broken out in the after part of the vessel, and such was the "uncontrollable rapidity with which the flames enveloped the vessel, "that in twenty minutes it was seen that the boats must be got out. "The sick having been successfully lowered, a number of the crew— "altogether about six-sevenths—proceeded to follow, when the main- "mast fell, and left the rest to find their own resources of escape "from the blazing ship. Clinging to ropes and holding on to spars, "there might have been a chance of succour, but for the fatal rapidity "of the flames, which in a comparatively short time reached the "magazine. On this blowing up the 'Bombay' sank in eight "fathoms of water, and ninety-one of her crew were drowned."

It would have been surprising if the American war furnished no illustrations of the danger of unprotected gunpowder. One explosion to which I shall refer is truly American in its magnitude.

"It would appear that on the evening of the 24th of May last, "while the ammunition was being removed from the Confederate "magazine in Mobile, which had just been surrendered to the Federal "forces, the ordnance stores, which were situated in the business "centre of Mobile, blew up with a terrific explosion. Three hundred "persons are said to have been killed, many wounded, and, according "to the chronicler, thousands were buried in the ruins. Eight entire "squares of the city were demolished, 8,000 bales of cotton destroyed, "and the steamers 'Colonel Cowles' and 'Kate Dale,' which were "lying at the pier, immediately sank with all on board. The value "of the property destroyed was variously estimated at from $3,000,000 "to $8,000,000. The cause of the explosion was unknown."

Tremendous as the explosions have been, to which reference has been made, we have reason to be thankful that we have not to refer to explosions of a still more terrific character. If the explosion which took place on the south side of the Thames had taken place on the north side, and if Purfleet instead of Erith, had been the scene of the disaster it is impossible to estimate what the extent of the calamity would have been. We know not and we can scarcely calculate what would be consequence if ten or twenty times the quantity which exploded at Erith was to be fired at Purfleet, and yet within a comparatively short distance of London many hundred tons of gunpowder are stored, and if an accident should happen there it would be destructive beyond all precedent.

Without becoming alarmists or prophets of evil we cannot but see that our modern ships of war are particularly well adapted to act as huge bomb-shells calculated to scatter destruction all round if an accident should happen in the magazine. The iron plates which are

bolted on to the ships' sides would fly off in all directions, and in their flight would not discriminate between friend and foe, but overwhelm with destruction whatever came in their way.

It is not, however, from extraordinary explosions like these that the chief danger and inconvenience arise to the public, but rather from smaller explosions which are of more frequent occurrence.

In the autumn of every year we hear of numerous explosions on the premises of fire-work manufacturers; it is the stock of unprotected gunpowder contained on these premises which renders them so dangerous. Nothing can be easier than to protect the gunpowder required for use by fire-work makers, as it would be perfectly easy to arrange a small machine which would separate the protected powder, and, at the same time, reduce it to the degree of fineness which the makers require. The losses arising from actual explosions represent but a small portion of the total loss and expense occasioned by the dangerous character of gunpowder. It is the care and expense necessarily bestowed upon the gunpowder for the prevention of accidents that furnishes the chief cost arising from its dangerous character. Hence the carriage of gunpowder is from three to six fold the cost of the carriage of other articles of commerce. If a ship takes but a small quantity of gunpowder, her rates of insurance are largely increased. The same increased insurance takes place on land, and if a man takes out a licence for keeping only 200 lbs. of gunpowder, the premium on the insurance of his whole premises will be greatly increased. The difficulties connected with the storage and transport of gunpowder are known only to those who are engaged in the business. A manufacturer who ships a considerable quantity of gunpowder stated that two pounds per ton would not pay him for the inconvenience and expense occasioned by the necessary regulations which are now imposed on the movement of gunpowder as compared with other articles of commerce. The same gentleman stated that, during the period in which he had been engaged in the business, his firm had lost, on an average, one powder-vessel annually, which had been lost without anything having been heard of it.

The difficulties and cost imposed on the regular shipment of powder causes a large clandestine trade to be done in the article, and it is not an uncommon thing for vessels to receive gunpowder on board under a different name, and in many cases shipments of it are made after the vessel has cleared out of port, and nothing of the kind appears on the ship's manifest.

The only way by which gunpowder can be carried cheaply is by shipping it in very large quantities on board of one vessel, the owners of which are tempted by means of increased freight to incur the risk. As far as the ship is concerned the risk is much the same whether the quantity of gunpowder put on board be large or small, but these large quantities expose the public to a terrible and unnecessary danger. As much as 400 tons of gunpowder have been put on board one vessel in the Thames, and when we remember that this is eight times the quantity which caused such destruction at Erith, we may well ask for some protection against such a dangerous neighbour as such a ship

must be. The "Lotty Sleigh" caused consternation throughout Liverpool by the explosion of 12 tons of gunpowder; what would have been the consequence if a vessel containing thirty times that quantity had exploded?

In addition to the losses by accident and the cost of precautions, must be added the anxiety and consequent suffering which the traffic in gunpowder occasions.

A shipowner, who was formerly a captain, informed me that on one occasion he took on board 20 tons of gunpowder, and during a voyage of three weeks he suffered so much from anxiety, that he determined never again to ship that article. The inhabitants of Liverpool, Edinburgh, Southampton, and other places, have recently expressed their anxiety as to the storage of gunpowder, and now that it is shown that perfect safety can be obtained, the public will scarcely be satisfied to remain in a state of danger.

The other evils which are removed by Mr. Gale's process, viz., the liability of gunpowder to damp and dust are less conspicuous than the dangerous character of the material, but they are scarcely less important. Gunpowder must be granulated. If it were reduced to impalpable powder or dust its action would be greatly impaired. In a state of granulation, air passes readily through the mass, and, as it carries more or less moisture, this moisture is imparted to the gunpowder. Unfortunately, different parts of a barrel of gunpowder will be differently affected by this action of the atmosphere, and the consequence is that in use it gives different results. A slight change will make much variation in the effect produced by gunpowder, and hence the importance of keeping it uniform. When packed in Mr. Gale's protecting powder, the atmosphere cannot affect it, as the powder is so extremely fine that air cannot penetrate. Mr. Gale's protecting powder is passed through a gauze-wire with 14,500 holes to the square inch; this will convey some idea of the fineness of the material. The effects produced by the powder becoming dusty from shaking, are much the same as those caused by damp —in both cases the results from the use of the powder are rendered uncertain.

The Government have constantly to sell large quantities of powder which have become damp or dusty, and after all the care that is bestowed on the matter, it is to be feared that powder is often supplied for use in very imperfect condition.

The transit of powder necessaily makes it dusty, and under these circumstances, the further the powder is used from the original source of supply, the more likely it is to become dusty, and, therefore, uncertain in its results. On this point I may appeal to the evidence of Colonel Vigley, who appears to have given much attention to the subject of gunpowder in India. He states:—"The great loss experi-
"enced when gunpowder is transported, especially over the rude
"tracts in some parts of India, causes it to be ground down to fine
"dust at the bottom of each barrel, and thus creates a very considerable
"waste and loss, which is greatly aided by the custom of allowing
"20 per cent. of space in each barrel to permit the powder to be

"shaken, and thereby to preserve the gunpowder from caking by "damp, which commonly occurs when packed in the ordinary way in "barrels."

It would be altogether beyond precedent if Mr. Gale's invention had passed unchallenged; and if other claimants for the honour of the discovery had not arisen, we might almost suppose that the discovery was of little importance. A writer in the *Times*, who signs himself "V. D. M.," and dates from Woolwich, is anxious to claim for Monsieur Piobert, a Frenchman, the merit of anticipating Mr. Gale. It appears that Monsieur Piobert made experiments with the view, as expressed by "V. D. M.," of "depriving the gunpowder of its "dangerously explosive character," and he recommended that one part of powdered saltpetre should be mixed with two parts of gunpowder. It would be scarcely fair to experiment with the prescriptions of others, but if I were to mix one part of saltpetre with two parts of gunpowder I should certainly ask the ladies to retire before applying a fusee. An application which leaves gunpowder in a highly combustible state does not appear to possess much value. If a few tons of gunpowder in this state were to be fired on board a ship, the total and rapid destruction of the vessel would be inevitable, for the fire could not be checked. Monsieur Piobert's own estimate is, that gunpowder in this state may be reduced in combustibility to the condition of mill-cake, the explosion of which is a constant source of accident in powder-mills. Monsieur Fadereff, who pursued similar experiments at a later date, relates, as the triumph of his process, that a barrel of gunpowder so prepared by him took 71 seconds to burn, the flame was six feet high, and, although it did not amount in the open air to an explosion, it is clear that such powder confined in a ship or building would cause a very serious explosion, and prove destructive to all around it.

About four months after Mr. Gale's invention was announced to the world, Lieut.-Colonel J. S. G. Riley, late of the Royal Cavalry, appears in print, and states that for many years he has been endeavouring to do what Mr. Gale has done. It seems that in December, 1864, he informed the War Office "that gunpowder, when stored agreeably to "his plan, instead of exploding en masse in the usual manner it "would merely burn like a squib." The reply he received was, "that the plan had been duly considered, but that it was not found "to possess sufficient advantage to warrant its adoption," and he now appears to feel injured because a different reception has been given to Mr. Gale's invention.

Colonel Riley's proposition, as given in his own words, is essentially different to Mr. Gale's. It is easy to see that a plan for storage which would leave the gunpowder to burn like a squib, gives no assurance of safety, and cannot be said to be a protection. Mr. Gale does not allow his powder to go off like a squib, or to go off at all. He is not satisfied until the powder is absolutely protected, not only from any approach to explosion, but also from combustion. Mr. Gale's protected gunpowder will not burn, and if a store containing his protected powder was destroyed by fire, it would be impossible to burn the gunpowder,

the greater portion of which would remain untouched either by the fire or the water which might be poured in to put out the fire.

The course adopted by Mr. Gale in announcing his invention was such as to enable Colonel Riley, if he pleased, to test his claim for priority of invention. Unlike most other inventors, who wait until their patent is fully completed before announcing it to the public, Mr. Gale published his discovery far and wide the moment that he had taken the preliminary steps for receiving a patent, and it was therefore open to Colonel Riley or any other person to claim priority, and their claim would be at once investigated and decided without the usual tediousness and costliness of legal proceedings. Colonel Riley appealed neither to the Patent Office nor to the public. Mr. Gale did both, and both have acknowledged his claim.

In conclusion it will be desirable to notice some of the objections which have been made to Mr. Gale's plan.

The first and most obvious objection is the increase of bulk, but as this does not involve increased cost, the objection is not a very serious one. The charge for the carriage of gunpowder is usually about sixfold that of ordinary merchandize, and protected gunpowder can therefore be conveyed at a less cost than unprotected, for with the element of danger removed, the charge for carriage will be reduced to ordinary rates, and where the carriage of one ton of gunpowder now costs say £6, the carriage of one ton of gunpowder and three tons of protecting powder will cost £4. The cost of storage is in like manner reduced. Under the present system expensive magazines must be constructed in out of the way places, but let the powder be properly protected, and it can be placed in ordinary warehouses in convenient localities.

The supposition that the gunpowder would separate from the protecting powder in transit has been repeatedly urged as an objection to Mr. Gale's process. This objection is purely imaginary. It is of course very easy to take a bowl of the protected powder, and, by giving it a peculiar motion, some of the grains may be brought to the top, but the question arises is such a motion given to the powder in actual transit, and experience answers in the negative. We have sent protected powder to all parts of England, to France, and to America, without the slightest symptoms of separation being discoverable. Mr. Cossham, who took out some protected powder and introduced the process to the American Government, thus writes on the question of transit:—

"Hill House, near Bristol, Oct. 27th, 1865.

"Dear Sirs,—I am happy to be in a position to answer most satisfactorily your inquiries as to the effect of transit on gunpowder mixed with your protecting powder. You will remember that on the 25th of August you placed under my care a box filled with the mixture. I took charge of it at Liverpool, and had it placed in the hold of the 'Scotia,' where it was subjected to all the rolling and tossing of over 3,000 miles of sea voyage. At New York it was tumbled about in a most unceremonious way, and subjected to the test of a very rough ride through the streets of New York in a cart without springs. I then took it with me for some thousand miles by railway in the States, the roughness of transit over which I can only compare to being drawn over a saw the wrong way; and at the end of the journey I found the mixture as perfect and the powder as completely protected as it was the day I left England. I have no hesitation, therefore, in bearing my unqualified testimony to the

fact that gunpowder mixed with your protecting powder will bear any amount of carriage without danger or risk.

"I am, my dear Sirs, very truly yours,

"HANDEL COSSHAM.

"To Messrs. Gale and Saunders."

Experience is the safest ground on which to rely, and with the experience we have gained we might safely undertake to send powder anywhere without danger of separation, but still it is interesting and useful to know why it is that the apprehended separation does not take place. In the first place there is no special tendency to separate, as both the gunpowder and the protecting powder are of the same specific gravity. In the next place no separation can occur without an extension of the bulk, and if no room is allowed for expansion the powders cannot separate. A small experiment will illustrate this. [The lecturer here filled a measure with protected gunpowder, which was then separated, and it was found that when separate the protecting material and the gunpowder much more than filled the measure.]

In barrels properly packed it is clear that the powder cannot separate. If, however, it is contended that in the shaking by carriage the powder will become more compact, and thus leave room for separation, it is obvious that this danger might be prevented by putting false heads to the barrels, so that if the powder was reduced in bulk, the false head would fall down on the powder and prevent it from separating. A still simpler plan is to put the powder in bags instead of barrels. Even if the bag was only partially filled, the weight of the bag resting on the powder would prevent it from separating.

One more objection may be referred to, although it is scarcely worthy of notice. It is said that the grit of the protecting powder is dangerous and injurious to the gunpowder. Any one who will take the trouble to feel the powder which we have here will at once see the folly of this objection. Powder which has passed through a sieve with 14,500 holes to an inch, is not likely to be gritty.

The necessity for sifting the gunpowder I look upon as far from being an objection. The fact is, that gunpowder, whether protected or not, ought always to be sifted immediately before being used, in order that the dust may be taken away, and any tendency to adhesion of the grains may be removed. If this was always done the results of rifle and other practice would be more uniform.

Any further objections which may be noticed in course of the evening I shall, by permission of the President, have pleasure in replying to at the close of the discussion.

The CHAIRMAN: There are several gentlemen who have heard this lecture with great interest, who are desirous that explanations should be given as to what the character of the protecting powder simply is, and they would also be glad to see any experiments that the lecturer may be induced to give.

Mr. SAUNDERS: This protecting powder is a mixture of powders, as we have found by experiment (one powder contains one quality, and another another) that a mixture of powders is very much better than any one simple powder. The quality required is that it should be dry, having no tendency to damp; that it should absorb moisture; that it should be non-adhesive, and that it should be non-combustible.

The CHAIRMAN: Can you not give us more information, because you are protected by patent.

Mr. SAUNDERS: There is no secret in it. We use a great variety of mixtures. For instance, glass powder is a very good protector. Glass powder and ivory black form also a very good protector. But we should use a variety of powders according to what we require. For blasting powder we should use a very simple and cheap protector. For sporting powder, of course, it would be very important to have the most perfect protector that we can have, a powder that would come off from the gunpowder as easily as possible; and also that would leave the gunpowder without change of colour; because, although what might not be of great importance practically, yet it would be of great importance as far as the prejudices of the sportsman are concerned.

Mr. STERLING LACON: The efficiency depends upon the fineness of it?

Mr. SAUNDERS: A good many qualities are required in the protecting powder, which we find out by practice. Mr. Gale has a remarkably fine touch, and directly he passes his fingers into the powder, he can tell in a moment whether it is a good protecting powder or not. But I can scarcely tell you what those qualities really are. We have found them out by practice.

A MEMBER: Cannot you tell us what those powders are composed of?

Mr. SAUNDERS: This mixture is composed of glass powder and ivory black. But we do not limit ourselves to that or any other mixture.

A MEMBER: In the course of your remarks regarding the accident during the process of moving the powder at Inkerman, you said that some foreign substance had got into it, by means of which this explosion took place. Is it not possible for such a thing to happen on board ship, unless the men are very careful? Looking at the manner in which sailors, who we know are not celebrated for their carefulness, handle things, might not something in the nature of a foreign subject get into the sieve while they are sifting, and cause an explosion which might be as tremendous? For as you observed, a small quantity will do as great an injury as a large one in blowing up a ship. Might not that danger occur? and have you any means to guard against it?

Mr. SAUNDERS: I am glad you have asked the question, because it gives me the opportunity of saying that this sieve is copper, consequently the powder coming into contact with it would not explode.

The CHAIRMAN: Perhaps it would be better to wait and answer all the questions at once.

A MEMBER: Will you be good enough to fire some powder in a protected and some in an unprotected state, that we may see what will happen?

A MEMBER: Would you state the cost of a ton of protected powder, and its liability to waste from being so fine and light? judging from what we have seen of its being passed through the sieve just now. What would be the cost, and what would be the weight, by reason of the operation of sifting?

Captain SELWYN, R.N.: Mr. Chairman, however, we may doubt a little of the value of a process for making that which we only think of as an explosive compound, inexplosive, we cannot doubt, I think, the extreme fluency and command of language with which the lecturer has put the subject before us. But although he has carried us from the explosions of magazines to the use of wet blankets, yet I do not see that he has given us any reason to spare him as naval and military men, whose opinion he solicited in the opening of his paper. He comes before this Institution knowing that it is principally, if not entirely, composed of members of those two professions; and that they estimate the paper entirely from their own point of view. If he seeks that we should express our opinion as to how far the process may be a valuable one in the storage of gunpowder on shore in large quantities in magazines, then we shall also want to know what are the dangers from explosion now existing? how far they may be eliminated without the use of any such mixture? how far the question of increased contents, increased bulk, and everything of that kind will influence the process? even if we do not go a step further, and ask what is the point at which you begin to bring back your compound into an explosive state? Do you do so when it leaves the magazine? do you do so when it gets into the

expense magazine? or, at what point, in short, between the gun and the manufactured powder do you begin to render it again an explosive compound, which it must evidently be at last? Now, with regard to the elimination of danger from magazines on shore, it is a remarkable fact, and one which I have had the opportunity of observing, that if a ship explodes at sea, almost invariably the effect of the explosion is confined to an upward direction. I do not see my friend, Sir Edward Belcher, here to-night; if he had been here he would have told you that I, as he says, attempted to blow him up in China. He had given me orders to set fire to a junk which had been taken, and he is an officer who likes his orders to be carried out promptly. He was at the mast-head with his sextant, and by the time he came down, and we had got a boat's length off the junk, she exploded. The incompressibility of the water generally determines the force of the explosion in an upward direction. Now, to a certain extent, that is also the case on shore. And if it were the practice to bury magazines to a certain depth underground, to carry them below the level of the ground, we should then find the total result to be confined to the crateral action of the gunpowder, and that the results would be expended in that direction without influencing the surrounding buildings very materially. The question of how far it might be desirable to rely on this compound in action is, I think, one which can only be fairly attacked by naval and military men, as the lecturer has indeed observed. We cannot, in considering the question, entirely forget that Mr. Gale has proposed to mix a very large proportion, 3 to 1, I think was the mixture of the compound substance, which is not in any degree conducive to the effects which we seek, of giving us projectile force. He forgets that although comparing the rate of freights and insurance on unprotected with the case of protected gunpowder, he may be able to show no increase whatever in the cost of transit; yet, that when he has to take, as in the Crimea, through a sort of Slough of Despond, a number of artillery waggons loaded with powder up to the front, the question of weight to be carried is very considerable; that in a ship the magazine occupies a certain space, and that we cannot afford to treble the space occupied by our powder; that in the hurry of a night action it is utterly impossible to suppose that we could stay to sift our charges before putting them into the cartridges. It is true that a certain proportion of cartridges are filled and are ready for action; but if the action is prolonged, necessarily a certain number of men are there filling the cartridges into the flannel bags, and if they are to stay to sift the powder, I am afraid one man will sift a charge with a certain proportion in it, and another man with another proportion in it, that, then, our ranges will be found to be utterly unreliable, and often for doing what we require, our guns will disappoint us. If it were an action with a fortress where mortar fire is required, then everything would depend upon the certainty of our range with given charges of powder. It follows that the slightest difference in the quantity of powder left among the sifted charges would produce a serious difference in the range, which at night we should be utterly unable to rely upon. We cannot see where the shell falls. We only know we have put in a certain charge, and laid the gun at a certain elevation, and that this ought to produce a certain effect. Those are practical objections which I am sure Mr. Gale will be obliged to officers of the two services for bringing forward. These are things which make us hesitate before we adopt anything, however beautiful it may seem. Although we have had some harrowing descriptions given of the effect of explosions, yet I do not consider that the proportion of explosions to the amount of powder stored, justifies us in saying that we are ready to sacrifice so large a proportion of efficiency for the sake of the elimination of that danger. I think it may be done in other ways. I think if even it is not to be done in other ways, that we soldiers and sailors will say, "Well, give us something that will do our work well and quickly," and we will consent to stay in danger, and to sleep over it, as we hitherto have done, who have been on board ship night after night, without ever thinking whether there were ten tons or one ton of gunpowder underneath us.

A MEMBER: I should like to ask the lecturer the price of the protecting powder with regard to transport. If you had to transport four tons of gunpowder you would have to add to the cost the expense of taking the three tons of protecting powder back?

A MEMBER: I think the lecturer said, if a building were set on fire, the protected powder would neither be exploded nor burnt; nor would it be damaged by the water that would put out the fire. I cannot understand that.

Major LEAHY, R.E.: Without detracting in any way from the merits of the invention by which the explosive character of gunpowder may be diminished by mixing it with a non-explosive material. I think there is one point upon which the lecturer has laid stress that he should be asked to explain. It is this, with reference to the accident in the siege train in the Crimea, to which he alluded; he referred that accident to the fact of the powder having been manipulated, and he claimed for this invention, mixing it with non-explosive material, a total absence from danger on that score. It appears however that you cannot use this protected powder without going through the process of manipulation, sifting it from the non-explosive material, and that the danger, with regard to the explosion of powder, arises more from the manipulation than the storage of the powder. You must go through this process of manipulation to get the service powder, and it has been already pointed out by previous speakers that it is very hard to draw the line at which you are to protect the powder and where the non-protected powder is to be used; and the lecturer has admitted that a small quantity of non-protected powder will do all the damage that a large quantity would. There is another point with regard to the explosion of the small arm ammunition in the catastrophe in the Crimea. I think it will be found that the small arm ammunition did not explode; but that the cartridges burned without exploding. Gunpowder, when it is divided into cartridges, the particles being separated by a non-explosive material, will not explode, but burn. I have seen a quantity burning like a bonfire.

Captain SELWYN: Permit me to add one other observation, which is, that occasionally, like Captain Wake, we want to blow up our ships or our forts; and then we want a sufficient quantity ready to do it well.

Captain BURGESS: I should like to ask whether any experiment has been made to ascertain that gunpowder, after it has been mixed with the compound, is as strong as it was before?

Mr. DILLON: I should like to ask how Mr. Saunders, when he mixes the powder, insures that it shall be perfectly mixed, and the grains of gunpowder perfectly separated, because when it is thrown into a barrel a great portion of the gunpowder might remain together without any portion of his protecting powder going near it.

The CHAIRMAN: I think every one has made the observations he desires to make, and that the meeting would be served by Mr. Saunders replying to those observations.

Mr. SAUNDERS: I have a very interesting list of questions to reply to, and I have much pleasure in replying to them. The first observation was with respect to the nature of sifting; and in relation to that it was also mentioned that a small quantity of powder exploding did as much harm as a large one. With regard to the present manipulation of powder, I believe it will be found that it would often be necessary to shift the powder from one barrel to another in order to preserve it from caking, and to keep it in proper condition. Of course, with Mr. Gale's process, that would have to be done once only, and that is as soon as possible before it is actually used; and when I said there was as much danger in a small quantity exploding as a large quantity, I meant that a few tons exploding was as dangerous to a vessel or a house as a hundred tons. I did not mean that a few pounds, which it is alone necessary to expose when this process is used, would be as dangerous as a few tons which must be kept under ordinary circumstances. With Mr. Gale's process it is necessary to sift the powder immediately before requiring it for use. Mr. Bidder's estimate is that two men, who might be the most common labourers you could imagine, would supply powder as fast as it could be required for a 100-gun ship. The process of separating is exclusively mechanical. It cannot be done wrong; it is so very simple that it is impossible to make any mistake about it, and the labour would be of the cheapest character. Surely, if two men can supply powder as fast as it can be required to keep 100 guns at work, I think, under any circumstances, they might be spared for the purpose. With respect to the cost of this protecting material, tha

would vary much with the kind of powder which you have to protect. For blasting powder I expect that the protecting material would cost about twenty shillings per ton. Probably, for Government powder, a more costly material would be used, but that would be entirely for the Government to determine. A powder which would protect the gunpowder with certainty can be supplied for thirty shillings per ton, but it is very probable that a higher priced powder would be better. Some gentleman has observed that to the cost of the protecting power has to be added the cost of the carriage back. He forgets that if you bring the powder back your second supply would only cost the cost of the carriage back. With regard to the point at which we make the powder re-explosive, that, as I said before, is a question more for military men to determine than for me; but from the little experience which I have had with gunpowder, I am strongly of opinion that gunpowder ought to be sifted immediately before it is used, because it is liable to cake and get damp, which causes have produced a great variation in the results under present circumstances, unless the powder is sifted just before it is used. I have no doubt that powder in cartridges does quickly alter its character. It may become caked or slightly dusty, in which case the character of the powder would be materially altered; therefore, I think the proper process would be to fill your cartridges as late as they can possibly be filled previous to action, and the powder kept in a protected state up to that time. With regard to the taking of the powder through the Slough of Despond, and the weight, and so on, which is added to it under these circumstances, I believe you will find that almost under any circumstances it is easier and cheaper to carry three or four tons of a material which is not dangerous than to carry one ton of material which is dangerous. I had a striking illustration of that a short time ago. A gentleman connected with the mines at Mexico came to us and said he was anxious to get our protecting powder. They had to take blasting powder over mountains on the backs of men, and with these men they were obliged to send an escort to see that they took the greatest possible care of it; yet, for all that, he said, "They blow up themselves, and blow up the gunpowder to such an extent that we lose a very large portion of it before it gets to the mines." Therefore, he said, he would far rather have our powder, which is four times as heavy to carry, than he would have the unprotected neat powder. That strikes me as a practical reply to the question as to the carriage of gunpowder through the Slough of Despond, which was referred to just now. Then, with regard to the space occupied by powder. Of course, on board ship that is extremely important; but my impression is that no increased space whatever would be required. At the present time you have to provide magazines with very thick walls; you have to give 20 per cent. space in your barrels; you have to allow a great deal of room for your barrels; you have to divide, and all the rest of it; and you are limited to one part of the ship to keep it in. You might dispense with your thick walls; you may put the powder in any part of the ship most convenient; and under these circumstances I do not believe you would require an inch more space than you do now. You would have more dead weight, which is decidedly an objection. But the question is whether the advantages overbalance that objection. Then with regard to the irregular sifting which was referred to, it is impossible for the sifting to be irregular. In practice probably a series of sieves would be arranged, to be worked by a handle, and the protected powder would be shovelled in at the top, and the two kinds of powder would come out completely separated at the bottom, so that the workmen would have no chance of making any mistake, or any irregularity in the result. I think the remarks I made at the opening of the lecture were sufficient to show that I never contemplated the sacrifice of efficiency for the elimination of a small danger. I am quite aware that a military man would never allow that for a moment; but it does strike me that both on land and sea it would be a great relief if it could be known that if an enemy's shot or shell came into a magazine it could not do any harm to the gunpowder. If a red-hot shell were fired into the midst of this protecting powder it would do no harm whatever. Another question asked was—how is it that the powder would not be damaged by water? Why, the water runs off this protecting powder the same as it runs off a duck's back, consequently it would not penetrate it.

A MEMBER: Can you show us that by and bye?

Mr. SAUNDERS: We can show you this by putting this powder into a glass and pouring water over it.

The MEMBER: Can you put it into the sieve afterwards?

Mr. SAUNDERS: You have a slight film of wet on the top: remove that, and you can afterwards sift it.

The MEMBER: You get your powder intact?

Mr. SAUNDERS: You get your powder intact; of course, Mr. Gale's plan is not adapted where an occasional blow up is required; still, a blow up can be had if required, so that I do not think we need apprehend any danger on that score. Half an hour would enable a couple of men to give you sufficient powder to blow up any ship. Here is the powder as strong as it was before? I think any one can see that the character of the powder cannot be altered by being mixed with another powder which is easily separated from it. This morning I bought a pound of Curtis and Harvey's powder, and mixed it with this protecting powder. It has been separated from it, and the powder is quite as clean as it was before it was mixed. It is obvious that the character of the powder remains unchanged: and, more than that, not only does the character of the powder remain unchanged, but the protecting powder prevents it from being changed. Powder is so liable to damp and dust that a barrel of powder filled this week would not be the same thing next week, it would not be uniform throughout. Lord Bury, when he gave his attention to the process, said he thought the great advantage was the preserving the uniformity of the powder, inasmuch as he found, constantly, that different results were obtained from different parts of the same barrel of gunpowder, as one part had been more exposed to the damp than another. Then, the question is asked, how is a perfect mixture guaranteed? I am glad that question is asked for it gives me the opportunity of explaining how the process of mixing is done. We take, say 40 lb. of gunpowder and 120 lb. of the protecting powder, and place it in a machine which may have come under the notice of some gentlemen present. It is a machine which is invented for the purpose of washing barrels, and it is very effective for that purpose. It turns the barrel in two directions at once. By putting these two powders into that machine, and by turning that machine, in a minute and a half the mixture is made in a most perfect manner. That is very easily tested, by mixing it in one barrel, then filling another barrel with the mixture, then divide that barrel into several parts and you see that you have the same proportions in every part of that barrel. The result in every case where we have made the trial has been perfectly satisfactory. Therefore, the mechanical difficulties of the mixing and the separation have been entirely overcome. With regard to the quality of the protecting powder used, I have no doubt that a good deal is to be learned on that score. It is possible we shall find out something better than we have yet on that point. It will be, of course, essential to use a powder which does not in any way affect the gunpowder, and which leaves it without deterioration in any respect. It is also very desirable to have the easiest possible separation; and although we have attained to a very great perfection in both those points, yet there is still, perhaps, room for improvement, and I dare say that improvement will be by practice obtained.

The CHAIRMAN: There are several gentlemen who would be glad to see some experiments.

Rear-Admiral SIR F. NICOLSON, Bart., C.B.: May I ask one question more upon what has just fallen from the lecturer? I am afraid he has been rather harassed by our questions. But I think if in his paper he had devoted his time a little more to the process, and to all the details which we have now heard from him, we should not perhaps have troubled him with so many questions. He stated, I think on the authority of Mr. Bidder, that two labouring men can supply 100 guns with the sifted powder. I wish to ask him whether he has any data on which that statement has been made? because I must say that, knowing the rapidity with which guns may be fired when necessary, I feel a little sceptical as to whether two men in action on board ship can supply 100 guns with the requisite powder.

Mr. SAUNDERS: Mr. Bidder is a remarkably quick calculator, and when the

question was put to him he said, after a rapid mental calculation—"100 guns!—two men could do that!" That is all I heard him say, and that is all I know about the matter. Still I have very great confidence on the result. Although I do not know the process entirely, still I think you may form something like an idea in your own minds by remembering how very simply and quickly men do separate by sifting. I daresay you have seen men in the streets separating gravel. One shovels it in and the other sifts it, and very soon a large heap is formed.

A MEMBER: How many cwt. of powder do these men separate in one minute?

Mr. SAUNDERS: I did not hear the particulars.

Mr. GALE: 1,200 lbs. I was present when Mr. Bidder spoke. He calculated that an old man of war carried 60 tons of gunpowder, and supposing the guns were fired off at the rate of 50 rounds in each minute, with a 12 lb. charge, it would take two men, with a little machine which we have, to supply the requisite amount of powder to fire off 50 guns in a minute on board ship.

A MEMBER: Suppose they fired 200 guns in a minute?

Mr. GALE: A thing not achieved by any naval or military man here. Mr. Bidder said, from his calculation, it would not be necessary to go on firing at this rate; that you would not have 50 guns in a minute fired with 60 tons of gunpowder right through.

Sir F. NICOLSON: The question is how much can these two men sift in a minute, sift and separate in a minute, so as to be useful?

A MEMBER: Might not that depend very much on the means used? If you had a powerful machine you might sift a great deal more than by hand.

Mr. SAUNDERS: It would depend very much upon arrangements such as the last speaker suggested. It would not be easy to give an answer off-hand. On board ship I take it the arrangements would be these: That the powder would be at the bottom of the ship; that an elevator would be provided to bring the powder from the bottom of the ship to the deck, or as near to the deck as it might be desirable to bring it for use; that the very same handle which shakes the sieves would turn this elevator and raise the powder from the bottom to the top of the vessel, separate and sift it at the same time. You might by the use of two, or four, or six, produce a flood of powder in that way, as fast as it could be possibly required. In fact, it would be as easy to bring up the powder and separate it, as it would be to bring it up only.

A MEMBER: Would you load the guns with loose powder?

Mr. SAUNDERS: Of course you have to fill your shells.

The MEMBER: No, the cartridges, how would you fill them? Would the two men do that?

Mr. SAUNDERS: We are comparing the use of loose powder. This process does not profess to fill cartridges. If you have to fill cartridges under the present system, of course you would have to do it under Mr. Gale's system. The only question is as to a supply of neat powder.

Sir F. NICOLSON: May I say a few more words, if I am not too troublesome? We came here, most of us, naval and military officers, to hear a lecture that would have some sort of bearing upon the practical use that this powder is to be put to. Granted that this powder can be protected, what we are very anxious to know is, if it is not really troubling Mr. Saunders too much, how, having mixed his powder and made it safe, we are to use it in action? It is for that reason I asked my former question. Now Mr. Saunders seems to suppose that the powder is brought up loose, "in a flood," I think he said. Then the guns are to be fired with it. I will ask any gentleman here how is that to be done? The powder must necessarily be made into cartridges before it can be used. If Mr. Saunders will be kind enough to tell us by what process this powder, after it has been sifted, supposing Mr. Bidder's somewhat vague calculation is correct, is to be put into cartridges ready to be used in the gun, we shall be obliged to him.

Mr. SAUNDERS: Do you do it by two men now? We have nothing to do with the filling of the cartridges. You want a supply of explosive powder, with a certain degree of rapidity. All that I can tell you is, that you can obtain that supply of explosive powder with any degree of rapidity which you may require. Of course,

if you have to fill cartridges under the present system, you will, also have to fill cartridges under Mr. Gale's system.

A MEMBER: We have not to do that. Our cartridges are ready filled on board men-of-war; but according to your system we must fill them in action.

Mr. SAUNDERS: I do not suppose that for a moment. You may carry a sufficient number of cartridges for your own use. Cartridges are not so dangerous.

A MEMBER: If you can have explosive powder in cartridges, what is the use of your protecting powder? Besides, our cartridges are all in cases, and no fire can get at them.

Mr. SAUNDERS: Very good. If they are there and are safe there is an end of that. It just confirms what I said, that cartridges are much safer than loose powder. Still you must remember that I am entering upon a point of the subject which I distinctly stated I could not undertake to do. I do not think, if you came here with the expectation of hearing how all this is to be manipulated in action, that you would have asked a non-military man to occupy the position I occupy this evening. I came here in the hope of hearing some explanation and information from military men. I can only say that Mr. Gale's process can be very readily applied, and the powder very readily restored. It is for military men to say how they will use the process. The President asked just now if some further experiments can be made. If agreeable, I will show you Lord Bury's test.

[Mr. SAUNDERS then exhibited some experiments to show the impossibility of exploding gunpowder protected by Mr. Gale's process.]

Captain SELWYN: I should be glad to have an answer to the question, as to whether he has by any mechanical test ascertained that there is none of the protecting powder left with any portion which he may have sifted—in the ordinary way it would be sifted in, not taking particular care to sift it—that under no circumstances is there a portion of the protected powder left? Because it is a most difficult thing, if we take any two substances and mix them intimately together, to mechanically separate them again.

Mr. SAUNDERS: This morning I took a pound of Curtis and Harvey's gunpowder. Immediately I received it I applied to it as good a test as you can apply in a rough way. I dropped it on this glass, and the result was that a great deal of dust was left on the glass. That I believe is as good a test as you can have as to the quantity of dust which is left on the powder. Now, after I did that, I separated some powder which had been mixed, and dropped that on the glass, and I found that the quantity of dust left was very much less from the sifted powder than it was from Curtis and Harvey's powder which had not been mixed, simply because it had been recently sifted, and it is my impression that powder should always be sifted almost immediately before use. I believe this is a test which gunpowder-makers generally use, and which they consider very satisfactory. I cannot by this light discover that any dust has been left on this glass after dropping upon it powder that has been mixed and separated.

The CHAIRMAN: Whatever the merits may be of the invention which Mr. Gale has put before the public, I am sure we are indebted to Mr. Saunders for the lecture which he has addressed to us. I am sure I may thank him on behalf of all who are here present. I would now ask Dr. Millar kindly to give us the information which he has proposed to do.

A NEW METALLIC CARTRIDGE FOR MILITARY PURPOSES.

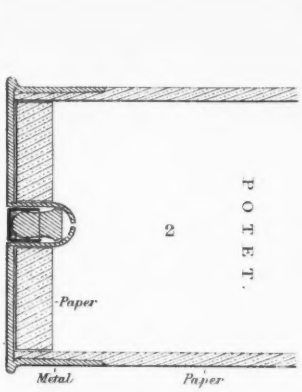
By DR. J. MILLAR, F.G.S., F.L.S.

Soon after the Government had last summer made known their intention to arm the soldier with a breech-loading rifle, I became much in-

terested in one which has been exhibited here, the invention of Mr. Burton, from America, a specimen of which rifle has been presented to the Museum of the Institution.

I was much pleased with the simplicity of its mechanism, the ease with which it could be manufactured, and the peculiar properties of its ammunition (Plate vi, Fig. 5). The cartridge is made of one piece of copper, and contains its own ignition round the rim, this ignition being the usual fulminate, inasmuch as this form of cartridge is the only plan by which the escape of gas can be permanently prevented, the fact of its being flame and water proof, and not liable to injury from rough usage, led me to believe that a cartridge of this kind was well adapted for military purposes. I was assured that it could not be exploded except by a pinching blow upon any part of the rim, and that the bursting of a shell amongst them only exploded those directly struck by it. On this point, however, I found in a little work published in America, where these cartridges are chiefly used, that the author says:—"I have re-"peatedly fired a ball into a box containing ten or a dozen of them, and "never failed to explode four or five, blowing the box to pieces, and "scattering the remains of the cartridges in every direction. I have "the remains of several such explosions now on hand, consisting of "shreds of copper, cartridges jammed out of shape, and the bullets "transformed into shapeless masses of lead, the whole bearing "evidence of a performance which it would be anything but agreeable "to have enacted in a cartridge-box hung on one's belt. The effect, "therefore, of a shot striking a soldier's box would be disastrous to "himself and those in his vicinity, while a similar accident to an am-"munition waggon would involve very certain destruction." Ammunition so dangerous as this is out of the question for military purposes, and to remedy so important a defect it occurred to me that if the copper case could be made to contain amorphous phosphorus and chlorate of potass, so arranged as that they could not come in contact except by a blow in a specific direction, the object would be gained. These substances are well known to be explosive only when brought in contact. To effect my object, therefore, I attach to the inside of the base of the cartridge (Fig. 6) some chlorate of potass, I then make a perforated metallic disc, to fit tightly into the case, in this I make a recess, to which I attach some amorphous phosphorus, but so that it does not come to the surface of the disc, I then place this disc above the chlorate so that the substances are opposite to and face each other, but do not come in contact, and then fill the cartridge in the usual way.

When the centre of the base of this cartridge is indented by the pin of the ordinary central-fire gun, the substances are brought into contact, and an explosion takes place, which fires the powder. A blow in any other part cannot bring the materials in contact, the cartridge, must therefore, be safer than any of those which contain fulminate.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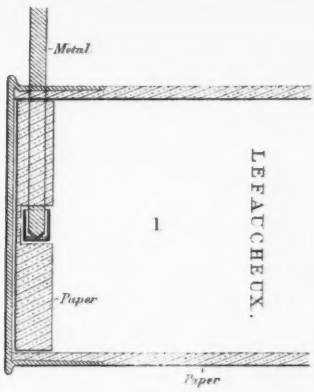
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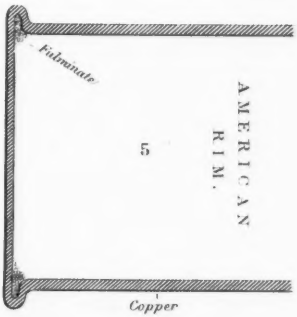
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5
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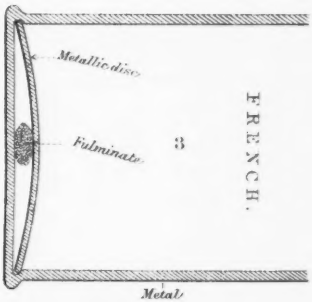
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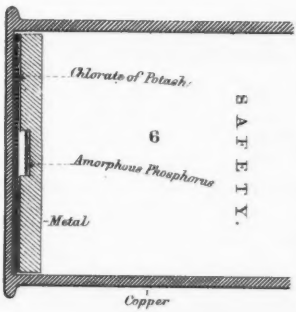
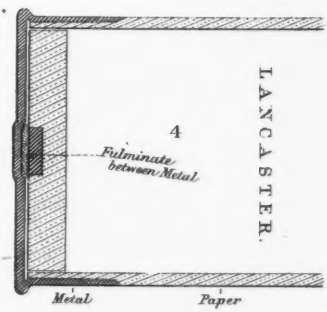
Fulminate
FRENCH.
3
Metal


Chlorate of Potash
SAFETY.
6
Amorphous Phosphorus
Metal
Copper


LANCASTER.
4
Fulminate between Metal
Metal
Paper

J Jobbins